TECHNOLOGY ASSESSMENT: PROCEEDINGS OF AN ERS WORKSHOP, APRIL 20-22, 1976

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TECHNOLOGY ASSESSMENT: PROCEEDINGS OF AN ERS WORKSHOP, APRIL 20-22, 1976. Compiled by W.B. Back, National Economic Analysis Division, Economic Research Service, U.S. Department of Agriculture. AGERS-31.

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PREFACE

Technological advance has been considered a source of progress over the centuries. In recent times, we have become increasingly aware of the indirect and delayed impacts of such advance on society. Frequently, they can be undesired and unintended. A systematic study of these impacts is coming to be known as "technological assessment."

This volume is the proceedings of an Economic Research Service (ERS) workshop on technology assessment conducted during April 20-22, 1976, at the National 4-H Center in Chevy Chase, Md. A paper summarizing results of a USDA assessment of minimum tillage is also included as an Appendix.

Most of the participants in the workshop were ERS professional staff, but the program included contributors and representatives from the Congressional Office of Technology Assessment (OTA), Congressional Research Service (CRS), National Science Foundation (NSF), Midwest Research Institute, and the U.S. Department of Agriculture's Agricultural Research Service (ARS) and Foreign Agricultural Service.

Two major purposes of the workshop were to facilitate improved communication among those within ERS engaged in technology assessment, and contribute to improved selection, planning, coordination, and conduct of the technology assessment components of our work.

Members of the planning committee for the workshop were W.B. Back (chairperson), Velmar W. Davis, Clark Edwards, and James L. Pearson. Editing for content was performed by W.B. Back, in close consultation with the individual authors.

Twelve of the workshop papers, primarily those reporting agricultural technology assessment activity or results, were published in the Fall 1976 issue of the Journal of the International Society for Technology Assessment. A double asterisk (**) in front of a title in this proceedings indicates the paper or an alternate version of it was published in that Journal.

CONTENTS

OVERVIEW OF THE TECHNOLOGY ASSESSMENT WORKSHOP

In the opening paper, Quentin M. West (ERS) gave two major reasons why ERS should expand its work in technology assessment (TA): (1) to perform the ERS mission better and (2) to enhance contributions of new technology to societal objectives of increasing productivity while reducing adverse environmental, physical, and social impacts. Joseph F. Coates (OTA) followed this presentation with a discussion of the inevitability of TA, and explained how technology can become part of the problem instead of the solution. Anticipating future impacts of current technological advance, he said, is as important for what he called "social technology" as it is for physical technology. Papers by Marshall E. Miller and W.B. Back (ERS) and Glen E. VandenBerg (ARS) focused on the interdependence of research and technology assessment and on how TA can contribute to research planning. TA's reliability depends largely on the soundness of a knowledge base developed through research. In turn, technology assessment contributes information useful for making decisions about research resource allocation.

In his account of major technological developments and their impacts over the past two centuries, Wayne D. Rasmussen (ERS) reminded us of agriculture's neglect of the social effects of technology. He constructed a hypothetical chain of events that showed how Eli Whitney's invention of the cotton gin could have contributed, indirectly, to the Civil War nearly 70 years later. The cotton gin was a prerequisite for the profitable expansion of cotton production. Without such expansion, slavery might have disappeared. Without slavery, there might not have been a Civil War.

Richard G. Stuby (ERS) made two main points in his paper on conceptualizing and measuring social impacts of technology. First, social impacts are not what remains when the economic factors are removed; rather, they encompass economic impacts. Second, the usual distinctions between qualitative and quantitative measurement obscure the differing, significant mathematical properties of phenomena.

On the second day of the workshop, speakers addressed the status of agricultural and rural technology assessment. Topics included the flue-cured tobacco harvester, the new 4-wheel drive tractor, integrated hog farming, twinning in beef cattle, coal mining in the Great Plains, boll weevil management, and irrigation technology. Midwest Research Institute, under contract from NSF, conducted the study on integrated hog farming. A major finding was that hog production will probably not be integrated as rapidly as poultry production was. The other studies were carried out by ERS researchers.

These papers showed where we stand in TA--the progress made and in the making. But, as a whole, they exhibited a major weakness of agricultural TA to date. It continues to stress feasibility of new technology for adoption within the food and fiber industries instead of addressing the broad social impacts of such technology.

Participants examined the utility of various TA methods on the third day of the workshop. Jean M. Johnson (NSF) presented a paper on "Role of Models in Technology Assessment." Papers followed on simulation, scenario writing, the Delphi technique, statistical methods, input-output analysis, parametric and linear programming, forecasting adoption, and benefit cost analysis. Most papers included examples or illustrations of methods in studies completed or in progress.

In the paper on Delphi, Douglas McNiel and Yao-Chi Lu (ERS) described how the technique was being used to forecast new technologies in meatpacking. Barry Carr (CRS), in his paper on scenario writing, gave many examples of the use of this approach in TA, including studies on alternative futures of U.S. agriculture and on minimum tillage. Apparently, no unique methods exist, judging from the papers, of making technology assessments. Rather, the existing research methods have varying degrees of utility within the several operations of technology assessments.

W.B. Back

W.B. Back
Agricultural Economist
National Economic Analysis Division

WHY ERS SHOULD EXPAND WORK IN TECHNOLOGY ASSESSMENT

by
Quentin M. West
Administrator, Economic Research Service

As an agency, ERS has a responsibility to develop and disseminate economic information for use by public and private decisionmakers concerned with the allocation and use of resources in agricultural and rural America. Let me recite a few of the things we do to carry out this mission.

We develop and maintain national and worldwide estimates of resource use and availability, output, and distribution of food and fiber. We identify interrelationships among economic forces, institutions, and governmental policies and programs. We develop short-term forecasts and long-range projections for both probable and possible future events. We evaluate the performance of the food and fiber sector in meeting the needs and wants of consumers and goals of society concerning such matters as quantity and quality of goods and services, income and income distribution, and quality of life. We identify probable adjustments in the food and fiber sector and evaluate their economic and social impacts on all segments of society. There are other responsibilities I could cite, but in short we are responsible for monitoring the progress, evaluating the impacts, and charting and predicting the course of that most basic segment of the economic system--food and fiber.

My purpose in elaborating somewhat on our agency's responsibilities is to tie down its relationship to technology and research on technology assessment. One definition of technology assessment I have seen is "the formal systematic examination of existing, newly emerging, or prospective technology with the objective of estimating first and second order costs and consequences (beneficial and adverse) over time in terms of the economic, social, demographic, environmental, legal, political, and institutional dimension of the impacts of the technology." It does not take too much imagination to link the importance of research results flowing from such assessments to the performance of ERS in carrying out the mission I have just described.

To carry this a step further, the importance of a major thrust area in technology assessment may be illustrated in several ways. We must consider the impact of technology and its role in the area of economic life with which we are concerned. There is no doubt that technology is a "prime mover" in economic progress or evolution, or that it plays a major dynamic role, introducing constant change in the stream of economic activity as new ideas are adopted and obsolete ones are abandoned. No other factor has done more to shape the structure of the existing food and fiber system or influence the outcome or performance of that system. Technology makes possible more efficient use of basic materials, and thus allows for the release of resources into the development of secondary and tertiary industries. This is a characteristic of a wealthy economy.

All of the sectors in the food and fiber system have their roots in the common soil of technology and have changed because of its impact. The farm inputs sector incorporates the latest technology into products and services sold to farmers. Technology's influence is clearly reflected in the farming sector with its decreasing numbers, larger units, mechanization, and large capital requirements; and the product market sector with its complex of processing industries, delivery systems, and mass merchandising which have led to an ever-increasing embodiment of services and product sophistication and proliferation.

Technology has played a major role as prime mover in the unfolding of the American economy, affecting the ebb and flow of economic activity as investments in major innovations and supporting industries at first accelerate and then slow down. It also is an

integral part of the competitive process as firms seek to achieve additional profits and growth through product and process innovations. Much of the product proliferation observed comes through attempts to tap latent consumer demand through new products or promotable differences in existing products. The structural, economic dynamics, and system output and dimensions implications of technology raise questions concerning costs and benefits; effects on capital stocks; flow of money into research and development; productivity; prices; costs; possible economic waste through excessive product proliferation and advertising; and other social and environmental concerns.

In summary, my first reason for expanding the role of ERS is that we can perform our mission better if we have a fuller knowledge of the primary, secondary and tertiary impacts of technology on agriculture and the total economy.

Another important reason for ERS interest is that there exists a crucial set of problems today affecting not only the United States, but the world economy. Some of these are concerned with increasing productivity in the utilization of resources to feed the rapidly growing world population; increasing productivity in the distribution system to lower costs; energy requirement and sources; and the environment. Solutions to these crises must be sought through new technology, and ERS must take a substantial and expanding role in assessing the consequences.

Very importantly, the assessments require a multidisciplinary approach. In this regard, we encourage the interagency cooperation needed for an effective research effort. The Department, through ARS, has a long history of development of knowledge and technology in the physical and biological sciences. Today, ARS is working on new means of agricultural production, processing, and marketing, including not only tools and machines but also methods of planting, plant varieties, livestock breeds, feeding formulations, climate modification, cell and tissue culture, photosynthesis, nitrogen fixation, organizational structures, grading systems, container standards, product preservation, quality control, and the entire infrastructure for transferring products.

The productivity of American agriculture is based on the continuing development of new technology from USDA, land-grant universities, and industry, plus their rapid adoption in response to economic incentives. There's growing concern that research levels will not be adequate to maintain rapid productivity increases in the future. At the same time, the agricultural research system has come under severe attack, beginning with "Silent Spring" and continuing with reports such as "Hard Tomatoes, Hard Times."

To some degree, these attacks are based on misinformation and a lack of understanding as to the benefits of new technology to the consumer as well as the farmer. However, there also has been some lack of understanding within the agricultural research system of the social and economic effects of the development of major new technologies. Unintended effects resulted simply because the projected impacts of new developments were viewed too narrowly. Thus, studies are needed to bring about research efforts focusing on technologies that provide the most promise for increased productivity, yet whose use avoids major adverse social and economic impacts.

You will note I have talked about the need for expanded effort. This does not mean that both ERS and ARS have been entirely lacking in knowledge of the need or efforts to seek solutions. In recognition of this need, ERS and ARS have conducted joint research on certain aspects of technology. ERS currently has eight economists at six ARS laboratories to provide economic support in their respective research and development activities and has cooperated with ARS in several other projects such as developing economic impact statements concerning EPA actions on certain pesticides.

These activities, however, fall short of analyses that consider major physical, economic, and social consequences. We now are aware of major societal concerns about environmental pollution, underemployed rural laborers, concentration of market power, and changing structure of agriculture which we now could be dealing with better if technology assessments had been made years ago. However, we still need assessments with respect to such consequences. An enlarged cooperative effort is needed to identify needed new technology for solving problems within the food and fiber system, to assure that interest groups' concerns can be addressed through factual information, and to provide an early warning system to avoid major adverse consequences of new technologies.

We did propose a budget increase item to fund an expanded program. While the idea was favorably received within USDA, we didn't get as much money as we had hoped to receive. We hope to receive greater funding in the future. We have also developed and approved within ERS a major new research project to serve as a focal point for technology assessments, the objectives of which are along the lines we have been talking about. Of course, all our research divisions will continue their efforts to properly account for technology as it affects their programs.

We see the need to improve the information base for public (and private) management of R&D resources and activities, or of the application of technology. The increased sensitivity of the public to the impacts of science is the underlying reason for an increasing public influence on the level of public resources devoted to R&D activity, and on how those resources are allocated among R&D activities. Public officials (including research program managers) are the primary clients for technology assessments--they are responsible to the public in R&D resource allocation decisionmaking.

We hope some specific purposes of an expanded program can be achieved (which contribute to the overall objective) such as:

. Identifying gaps in technology within the food and fiber system and thus aid in insuring that needed innovations come on stream to meet human needs and societal goals.

. Facilitating effective monitoring of R&D activity.

. Providing early warning signals of problems that could be associated with a particular technology and which may warrant development of other solutions.

. Informing potential users of their opportunities for net gains, and of benefits and costs likely to accrue to others as the technology is adopted.

. Informing those likely to experience the indirect impacts about the nature, timing, and magnitude of those impacts.

. Informing public officials about how the new technology, if adopted, would impact on various local, State, and national objectives.

This workshop has come about because of our reorientation and commitment to analyze the broader impacts of technology. It should enable us to take a big step forward.

THE INEVITABILITY OF TECHNOLOGY ASSESSMENT

by
Joseph F. Coates
Office of Technology Assessment
U. S. Congress

Technology assessment may be defined as a kind of policy analysis which attempts a systematic study of all the consequences for society of the introduction, expansion, or modification of a technological development or project. Technology assessment includes the usual considerations of cost effectiveness, feasibility, and safety, but goes well beyond them to look at the impacts on society from interactions with other technologies as well as to latent, indirect, unintended, and delayed effects on man, his environment and all his institutions. The goal of technology assessment is to examine the risks, the benefits, and the consequences implied by technology and to put into the hands of a decisionmaker, or those influencing decisionmaking, better information about the possible consequences of alternative actions.

Some Characteristics of Technology and Its Consequences

Social Technologies

There is certainly no difficulty in agreeing that electric lights, tractors, automobiles, water works, pacemakers, and hybrid corn are examples of physical or biological technologies. It is important also to recognize an application of science that I choose to label social technology. USDA has been very much involved with such technology.

If we take technology to be the application of human arts and science to the achievement of human goals, it is apparent that food stamp programs, extension programs, the Morrill Land-Grant College Act of 1862, farm subsidies, the county agent system and most laws, regulations, and institutions are examples of social technologies. The analogy to pesticides and hybrid corn as technologies is important because social technologies are subject to the same king of analysis as are the physical and biological kinds. Social technologies also generate the same kind of secondary, tertiary, unanticipated, or surprising consequences. Because social technologies comprise the principle management tools of society, what is managed is likely to go awry if the tools are defective.

Man-Made World

Almost all Americans live in a totally man-made world. With the exception of some farmers, foresters, and miners, there is virtually no direct contact between most Americans and Nature in the raw. Science and technology are so much the principal forces shaping our socio-economic environment that there is literally nothing that we see, feel, touch, hear, smell, or eat, that was not either generated or dramatically changed by science and technology in the past 50 to 75 years. This state of affairs is unique in the history of civilization.

Just a few decades ago, when we were more in contact with nature, we had an understanding of nature. Over thousands of years, we came to understand what hurricanes, drought, insects, disease, plagues, birth, and death meant. We built institutions to accommodate them. In contrast, we know virtually nothing about the man-made world in terms

of its elasticity, its forgivingness, its response to extreme stress, its susceptibility to collaspe. An yet, that is the world in which we now live and which is of basic importance for the future.

Problems

Another important point is that there are no major societal problems which are not direct, or close to being direct, consequences of the development of science and technology in the past 50 to 75 years. I would say that is true regardless of whether one is talking about urban congestion, the flight to the suburbs, pollution, alienation among white and blue collar workers, the generation gap, international trade problems, war and peace, crime, or deterioration of education. The problems of society are generated directly by technology in the sense that new technology creates new ignorance and uncertainties, new opportunities, and new risks.

Promethean Opportunities

There is literally nothing we cannot begin to think about, plan for, investigate, or explore in order to make reasonable, rational movements toward manipulating, controlling, managing or doing. We have almost achieved the Promethean goal. Our collective capabilities embrace not only prosaic day-to-day use of goods, products, and services, but also the grandiose, such as managing and revamping of the planet, or continental engineering. With infinite opportunity, but with finite resources, choices must be made. It follows from the foregoing discussion that we must begin to think and plan in new ways for living in a totally man-made and -managed world.

The Dominant Commodity

The fundamental shift in the labor force in the United States suggests another kind of transformation. At the founding of the republic, 95 percent of the population was rural. During the 19th century and early 20th century, we experienced major industrialization and urbanization. Another transition during this century was characterized by a shift of the bulk of the labor force the service sector. But, even that does not reveal specifically the nature of the transformation. Right now, somewhere between 30 and 50 percent of the labor force is dealing with the dominant commodity in the United States. And what is that commodity? It is not grain, wheat, corn, automobiles, oil, energy, or the like. Rather, the dominant commodity in the United States today is information. A third to half of the labor force is one way or another in the business of producing, utilizing, packaging, disseminating, assimilating, transmitting, or transferring information.

As information becomes more important, the fountainhead of information, science, becomes more central. Institutions which specialize in information are becoming the central institutions of our society. USDA is right in the middle of this transformation.

The Special Feature of Technology in America

Every society depends on technology. What is special about technology in America is it scope, scale, integration, and complexity. Those are the things we have to learn to cope with. Consider the A&P and Safeway. Together, with their 5,000 or more stores, they sell a large percentage of the groceries in the United States. This is unheralded any place else in the world. Consider Sears, the retailer. It alone accounts for 1 percent of the gross national product. But concurrently with concentration in industry and contrary to popular expectations of only four or five decades ago, we find another characteristic of much of America, the simultaneous combination of uniformity with diversity. Look at the Sears catalogue. It isn't just a miscellany; its 1,500 pages offer totally integrated households. You can buy goods to outfit whole households in numerous and harmonious ways.

The Rise of the Middle Class

A central social change in America is the rise of the middle class. Four or five decades ago, we could identify several distinct classes in America: farmers, agricultural workers, unskilled workers, semi-skilled workers, skilled workers, bourgeois small businessmen, managers, and factory owners. Today, most of that is gone. We have an enormous middle class to which most Americans belong. On the perimeters are some very wealthy and some very poor, but many of the poor are struggling to make it into the middle class.

What does the middle class do when confronted with a problem? It calls upon institutions. If an institution does not exist, create one. If the institution is not working, attack it. If a new problem emerges, create a new institution. A result of this process is perhaps best exemplified in a single number, the existence of 79,269 government entities in the United States (as of 1972). This may be more than a needed order of magnitude, maybe two orders more. But government is largely a response to this middle class penchant for institutionalizing concerns. You are dependent now on a new constituency, the middle class. Highly educated and prosperous, it challenges, questions, and insists on ventillating your organization. It insists on challenging the way you do business because it has the tools to ultimately force you to change your ways.

The Techno-economic Planning Criteria

Only three basic techno-economic planning criteria enter into the decision to open a Chinese laundry, a MacDonald's quick food stand, to build the Grand Coolee Dam or the Alaskan pipeline, to construct a water works or a public health facility, to market a new camera or car, or to build cable TV in town. These three criteria are: a) Can you build or develop it? b) Will somebody pay the bill? c) Is it safe? When one considers all the troubles that now beset us, be they crime in the streets, urban congestion, alienation of workers, disruption of family, environmental pollution, international tensions, or whatever, each has become a major national issue because of the side effects of technology. But it was factors other than the techno-economic planning criteria, factors not entering into the decisions of buyers and sellers, that seem dominant in creating our problems.

Those criteria are enormously powerful--they built America. But as our society became integrated, complex and nationwide, as the scale and scope of enterprises grew larger, and as the rate of propagation of technology accelerated, these three criteria became insufficient. Increasingly, the consequences of technology accrued outside the chain of buyers and sellers. The awareness of the strength and weakness of our traditional planning criteria has spawned major movement in the public and private sectors to come to grips with what the economists call externalities.

In the context of the mission of USDA consider the three planning criteria in relation to the following:

. Prepared food in the United States is diverse, plentiful, good, and cheap. Yet, much too often it is flat, tasteless, over-caloric or "hyped-up" with dyes, fillers, and additives of questionable nutritive value.

. Consider the theme of "Hard Tomatoes, Hard Times"--all those undesirable side effects associated with agribusiness. Should it be a minor cottage industry to grow decent, tasty summer foods? And, should it in turn be an arcane art to locate them? Are the social costs of this situation justifiable?

. Consider the case of the depopulation of the countryside. What has USDA wrought?

. Take the bizarre status of land tenure in rural America.

. Consider the case of the energy intensiveness of agriculture. The story suddenly exploded on the front pages 3 years ago. The department could have analyzed that trend and its implications any time over the past two decades.

. Take the case of the sacrifice of suburban land, high quality agricultural land, to incidental short term economic forces. What happened to the Garden State?

. What about water pollution and toxic residues as a side effect of pesticides?

. Take the case of concern about malnutrition.

. Look at the fantastic story of the tobacco industry. With overwhelming epidemiological evidence on hand for a decade, we remain locked into generating and propagating the product year after year.

None of these effects and concerns are part of the chain of buying and selling. But, somehow they all evolved because of the scale and the scope of incidental technological consequences. Few would care if you fouled up a few acres or polluted minor or tributary waters somewhere in the middle of nowhere. But, when it happens to major water supplies and land mass everywhere, it is both important and unnecessary.

Four Decades of Change

Exhibit A is a list of 60 long term trends that are affecting all our institutions. But, let me skip over them and rather focus on some of the more specific structural changes within the agricultural sector. By structural, I mean fundamental, built-in changes in society which demand new ways of handling our social and economic affairs. I will compare the thirties with the seventies.

A comparison of food and agriculture systems in the thirties with that of the seventies highlights many shifts in society, the economy, and technology which should influence the mission of the Department, its structure, strategy, and operation, and its policies.

In the thirties, there were many small farms. In the seventies, farms are larger, fewer in number, and are the homes of only 4½ percent of the population.

The agriculture was labor and animal intensive. Now it is energy intensive in terms of equipment, fuel, pesticides, and fertilizer.

Then farming tended to be general with diverse crops and livestock. Now. specialized cropping is the mode.

Then the last stages of food preparation were at home. Now, commercial food preparation--be it frozen, dried, canned, precooked, or whatever--is predominant.

Then the farm block was politically potent; today we see the rise of consumerism and environmentalism.

Then there was great faith in technology and universal optimism about what it could do. Today there is growing concern about the side-effects of pesticides and herbicides, limitations on water resources, residual toxic material, food and nutritional quality, and gustatory acceptability.

The agriculture was largely empirical and experiential. Today agriculture is highly technological and growingly scientific.

Then the marketing system was complex and diverse, but with large numbers of buyers, sellers, processors, wholesalers, and retailers. Now there is a high degree of integration throughout the whole process.

Then foreign food aid was largely private and in response to disasters. Now Government is involved in large-scale food and technical assistance programs.

Then most nations were self-sufficient in food. Now large numbers import to acquire a necessary margin of commodities.

Then international food trade was largely in private hands. Now governments play an increasing, if not dominant, role.

It should be clear from these as well as other long term trends that changes in the agricultural sector warrant new and sophisticated ways of thinking, new study strategies, new ways of formulating policy, a broader range of considerations entering into policy alternatives, and new policies. To a substantial degree, this is a call for technology assessment.

The major transformations in your Department's business are the result of fundamental changes in society. It would be both unfair and incorrect to suggest that the Department has been oblivious to these changes. The Department has been involved in technology assessment for a long time, at least as far back as the late thirties, when one study anticipated the consequences of mechanization of cotton. In the past decade there have been a number of partial assessments and a number of future-oriented policy studies under departmental auspices. The need is not to begin this type work, but to

expand and improve it. The need is for more open and effective assessments with a stronger future and policy orientation. With that as a goal, what are some of the characteristics of the department that have to be taken into account? First of all, I think there is a fundamental conflict in your charter. The goal of bringing cheap food to the consumer conflicts with the mission of preserving the small farm.

Second, I think the Department suffers what most of America suffers. USDA is a behemoth bureaucracy. The fundamental rules of bureaucracy are known and well established. They organize, routinize, quantify, and trivialize. The cardinal rule is "ignore your mission and protect yourself." To recognize this truth is equivalent to recognizing that a certain animal or plant has a certain set of characteristics. To deny it, would be a grievous error and an impediement to progress.

In view of the internal rules of bureaucracy, it is important to understand what the basic rule for change is. It is nearly absolute and simple. Bureaucracy does not, cannot, has not, and will not ever undergo major change from internal forces. Bureaucracies only undergo major transformation from external forces, especially fear. Fear can be therapeutic. It can also be destructive.

Another factor influencing technology assessment within the Department is the obsolescence of much of its organization, management, structure, mission, and data collection. Now, obsolescence is the word I used. I didn't say obsolete. Obsolete means no longer of use. Obsolescence only means that whatever you have been doing is of decreasing utility, or on the way to becoming obsolete.

All these factors have to be taken into account in planning for technology assessment within a departmental framework.

It would be inappropriate to go into detail on what technology assessment might include, or how it might be done. Since much of your time in the next few days will be spent on the question of how to do technology assessment, let me pass over that, noting only the 10 elements highlighted in Exhibit B.

I hope that during the next 3 days you will begin to consider such questions as where do we start and what priorities do we set. You will experience disaster if you begin by undertaking a subject concerning a major departmental commitment. Every worthwhile technology assessment I know of has generated bad news. It has to, because it examines heretofore unquestioned assumptions. Getting at something representing a major commitment with the department's management is guaranteed to run you up against a stone wall. So, the question of where to start and how to start are, from an institutional point of view, as important as the question of how to do a technology assessment.

A caution: Your natural tendency will be to quantify, to gather data, to build models, and to do quantitative analyses. All of that is good. But your tendency also is to stop there. That is only the beginning. I assure you most of the interesting effects you ought to be concerned about will relate to long term futures and to policy options. These, of necessity, involve softer and more speculative tools than people addicted to quantification find congenial.

A holistic approach to problems must be an iterative process. It is a process with which no one will be entirely satisfied. You must begin to address the questions of participation by those with whom you have not formerly dealt with. How do you bring in the interested parties, the stakeholders? Well, these are only some of the issues and opportunities you will face in technology assessment.

Exhibit A

General Long-Term Societal Trends

1. Economic prosperity, affluence and inflation
2. Expanding education throughout society
3. Rise of knowledge industries and a knowledge dependent society
4. Relative decline in common knowledge of the physical world
5. Urbanization/metropolitanization/suburbanization
6. Rise of the middle class society
7. Cultural homogenization - the growth of a national society
8. Growth of permanent military establishment
9. Mobility

    a) personal
    b) physical
    c) occupational
    d) job

10. International affairs and national security as a major societal factor

Technology Trends

11. The centrality and increasing dominance of technology in the economy and society
12. Integration of the national economy
13. Integration of the national with the international economy
14. The growth of research and development as a factor in economy
15. High technological turnover rate
16. The development of mass media in telecommunications and printing
17. An awareness of the finitude of resources

Trends In Labor Force And Work

18. Specialization
19. Growth of the service sector
20. Relative decline of primary and secondary employment
21. Growth of information industries, movement toward an information society
22. Expansion of credentialism
23. Women, blacks, and other minority groups entering into the labor force
24. Early retirement
25. Unionism
26. Growth of pensions and pension funds
27. Movement toward second careers and midlife change in career
28. Decline of the work ethic

Trends In Values And Concerns

29. General shift in societal values
30. Diversity as a growing, explicit value
31. Decline of traditional authority
32. The growth of anti-authoritarian movements
33. Increasing aspirations and expectations of success
34. Growth of tourism, vacationing and travel
35. General expectations of high level of medical care
36. General expectations of high level of social service
37. The growth of consumerism
38. Growth of physical culture and personal health movements

Exhibit A (CONTINUED)

39. Civil rights, civil liberties expansion for Blacks, Chicanos, gays, and other minorities
40. Growth of women's liberation movement

Family Trends

41. Decline in birth rates
42. Shifts in rates of family formation, marriage, divorce and living styles
43. The growth of leisure
44. The growth of the do-it-yourself movement
45. Improved nutrition with the consequent decline in the age of menarche
46. Protracted adolescence
47. Decline in the number and significance of rights of passage, birth, death, marriage, etc.
48. Isolation of children from the world of adult concern
49. The acculturation of children by other children.
50. The growth of a large, aged population.
51. The replacement of the extended family by the nuclear family and other living arrangements

Institutional Trends

52. The institutionalizing of problems. This is the tendency to spawn new institutions and new institutional mechanisms for dealing with what were in the past personal, private, or nongovernmental responsibilities
53. Bureaucratization of public and private institutions
54. Growth of big government
55. The growth of big business
56. Growth of multinational corporations
57. Growth of future studies and forecasting and the institutionalization of foresight mechanisms and long-range planning
58. Growth of public participation in public institution and private institution decisionmaking
59. The growing demands for accountability and the expenditure of public resources
60. Growth of demands for social responsibility.

Exhibit B

Components Of A Comprehensive Technology Assessment

1. Examine problem statements
2. Specify systems alternatives
3. Identify possible impacts
4. Evaluate impacts
5. Identify the decision apparatus
6. Identify action options for decision apparatus
7. Identify parties at interest
8. Identify macro system alternatives (other routes to goal)
9. Identify exogenous variables or events possibly having and effect on 1-8
10. Conclusions (and recommendations).

ALTERNATIVE STRATEGIES IN EXPANDING AGRICULTURAL TECHNOLOGY ASSESSMENTS

by
W. B. Back and Marshall Miller
Economic Research Service

With increasing concern about socioeconomic adaptation to change and about the effects of agricultural technology, adjustments in scientific research and the activities of agricultural scientists seem inevitable. Agricultural scientists tend to be highly specialized, but assessment of the wide-ranging consequences of technology requires a coordinated, multi-faceted investigation. The focus of this paper is on strategies which can be used to establish relationships between technology assessment and scientific research.

Comparison of Research and Technology Assessment Processes

Agricultural scientists usually organize their research activities in the following order:

. Recognize a practical or intellectual difficulty.

. Initiate research.

. Analyze the practical or intellectual difficulty. This may call for a review of the literature and an expression of relations among elements of the problem (model building).

. Postulate alternate logical and empirically testable relations which would resolve the difficulty.

. Design means of acquiring data or evidence.

. Conduct experiments, surveys, and other data gathering activities.

. Analyze primary and secondary data.

. Evaluate the results in terms of whether the problem was solved, the need for additional research, and whether new issues were raised. (Evidence of new research needs may lead to a reiteration of the entire process.)

While this pattern is the same for basic as well as applied research, the more the scientist is concerned with basic knowledge, the less attention he pays to practical aspects and to the application of his findings. Scientists can isolate themselves in a world of strictly intellectual problem solving. Those who do sometimes are accused of doing their own thing, rather than responding to real world priorities. It should be realized that basic research can be an essential part of research and development, and that practical applications of new technology can be an unanticipated consequence of basic research. This sometimes is used as a rationale by scientists to justify stress on basic research. Major technological breakthroughs usually start with major advances in pure knowledge.

Certain phases of technology assessment may be more akin to art than to science or research, but the key processes in TA parallel the early steps (the creative part) of the scientific method. TA originates from anticipation of practical or intellectual difficulties. It includes problem analysis, state of knowledge assessment, model building, and estimates of the consequences, of technological options. Although TA improves perceptions of technology and its consequences, and necessitates the seeking of new methods of inquiry, these assessments may not add much to scientific knowledge as such. Unlike research, especially basic research, the validity of the postulated consequences are not tested by direct observations of fact. Such empirical testing is essential for increasing scientific knowledge. Because the standards of scientific

research tend to be adopted as principles of professional conduct by scientists, it is sometimes difficult to involve agricultural scientists in technology assessments. Still, we believe the expertise of agricultural scientists must be used in these assessments. Otherwise, a high percentage of such assessments may not be reliable as bases for research management or policy decisions.

Complementary relations exist between scientific research and TA. We will now take up those relations and the alternative strategies.

Alternatives Strategies

At least three strategies may be pursued in expanding agricultural technology assessment. They are: total integration of TA with scientific research; pursuit of each as a separate activity; and, a mixed strategy--some integration and some separate activities.

Integration of Research and Technology Assessment

Two major factors favor this strategy: There already exists a significant degree of integration; and, existing administrative processes for project development, review, approval, and funding could be readily adapted to a more integrated approach.

Agricultural scientists regularly consider some of the impact of technology when proposing new R&D activity. Their justifications stress the direct impacts. However, justifications frequently include consideration of soil conservation, quality of the finished products, health and safety questions, energy consumption, and rural development. Agricultural scientists have provided much of the intellectual leadership in these areas.

Undoubtedly, many justifications have not dwelt on such indirect consequences because they were considered insignificant. It is conceivable that many proposals for agricultural R&D were modified, or discarded, because of anticipation of adverse indirect impacts. But, the records will never show it.

The history of the indirect effects of agricultural technology indicates that not enough attention was given them by agricultural scientists. Explicit, formal, and systematic analyses should replace subjective judgments of scientists in assessing the effects of agricultural technology.

Let's turn now to adapting existing administrative processes to accommodate TA. The existing project development and approval processes generally are the following:

- A scientist submits a project proposal for official review and approval.
- Research administrator obtains review and either approves or disapproves the proposal subject to availability of funds.
- If extra funds have to be appropriated, the appropriate public officials review the proposal and act accordingly. Officials involved may include the Secretary of Agriculture and others.

Generally speaking only proposals for major research efforts require new appropriations.

Under existing law, environmental impact statements are required for all major new federally financed public projects. One may ask, why not also require impact statements for new publicly financed R&D projects which may have major indirect consequences? Rather than a requirement established by law, this could be an administrative procedure. Rather than require a public review of the impact statements accompanying research proposals, the review could be done within the agricultural establishment. The impact statements could accompany requests for extra appropriations all the way to the Congress. They also could be used by research administrators as part of the rationale for establishing research priorities and for providing feedback to the scientists on a need for modifications of research proposals. Needs for research on side-effects, or to redo or modify the impact statement, are two examples of feedback to scientists.

There are a number of other reasons for integrating TA with scientific research. They are:

- Maximum use of the expertise of the scientists, both in the assessments and in the planning of research projects, would be allowed.
- Timeliness would be improved.
- It would broaden and enhance the expertise of scientists for performing technology assessments, and it would allow greater scientific contribution to the solution of society's problems.

There are four possible disadvantages:

- Research would be fragmented to the extent that many projects could be required to produce a single technology. Therefore, single-project technological assessments may not aggregate into meaningful results.
- The aggregate of several interrelated technologies may be required to produce accumulated social effects sufficiently large to warrant study.
- Many technology assessments could be cursory, limited to the interests of the scientists, or too discipline oriented; and
- the research process could be slowed or delayed.

Separable Research and TA Activities

The disadvantages of integrating research and TA are serious enough to rule out an exclusive reliance on that strategy. The logical alternative is to pursue the activities separately.

By separate prusuit we do not mean to imply the lack of necessary or desirable interrelations between the two. Rather, we mean that the assessments will be organized and carried out without regard for the processes of project planning, review, approval, and funding. Scientists whose work could be most directly affected by the results of the assessments may or may not participate in them.

This strategy would entail creation of staff groups to organize, administer, or conduct the agricultural TA's. How the results of such TA's are used would depend on the needs and judgments of potential audiences. The point is that complementarities of the activities can be enhanced through management.

When TA and scientific research are carried out separately, there are two relationships of fundamental operational significance: Available scientific knowledge becomes a basic input; and TA may reveal, as feedback, significant deficiencies in knowledge which otherwise could go undetected. In short, the degree of success of a TA carried out as a separate activity is largely dependent upon the availability and use of knowledge or data obtained through research.

In any activity involving application of knowledge, knowledge has to be the basic input. The assembly, organization, and interpretation of existing information permeates the process of TA. The complexity of these tasks arises mainly from the fragmentation of scientific knowledge among disciplines and specialists within disciplines, from the highly technical language used in reporting results of scientific inquiry, and from the sheer volume of literature that has to be researched. Such complexity would be near-impossible to overcome without the help of scientists from the various disciplines involved in TA. This means a major portion of resources available has to be devoted to the assessment of knowledge.

Informational gaps frequently are closed by making assumptions, but in making such assumptions, the goal is expediency, not creation of reliable substitutes for knowledge.. Every assumption in an analysis reveals a potential need for new research. This is what we call feedback. It would be more effective in stimulating new research if the scientists themselves discovered the gaps while participating in TA's rather than to receive it from TA literature or from other participants in the assessments.

We believe that the knowledge gaps are more obvious in areas of indirect and delayed consequences of technology than they are within the system of direct or user effects. This is because R&D has focused on technical and economic feasibility to potential (private sector) users rather than on issues of social feasibility. Another hypothesis we hold is that major information gaps for purposes of technology assessments can be adequately revealed only through extensive assessments of knowledge as

an activity related to these assessments.

Some advantages of the separate strategy are:

- The scope of individual assessments would be determined independently of individual R&D projects.
- Flexibility would exist for allocating resources to TA in relation to priorities.
- The advantages of using interdisciplinary teams could be exploited; and,
- the advantages of specialization in TA could be achieved and enhanced.

Some potential disadvantages could be:

- Lessening of a self-felt responsibility for TA, or any effects of technology, by individual scientists.
- Less influence of the results of the assessments on research resource allocation than may be desired.
- Less total manpower devoted to TA than may be desired; and,
- the fate of a TA program could rest entirely on the abilities of a few people.

Conclusion

The risks associated with each strategy discussed so far may be reason enough to warrant a mixed strategy--the simultaneous implementation of integrated and separable research and assessment strategies. To achieve coordination, maximize complementarities, and minimize duplication, however, careful planning of the entire operation would be needed. Administrative guidelines would need to be developed, spelling out which technologies or impacts would be assessed under the leadership of the scientists, and which by the staff group specializing in TA. We believe a mixed strategy could be easily initiated and implemented within the publicly supported agricultural research establishment. It only requires planning and a collective decision to do it.

TECHNOLOGY ASSESSMENT, A TOOL FOR PLANNING RESEARCH

by
G. E. Vanden Berg
Agricultural Research Service

The function of the Agricultural Research Service (ARS) is, obviously, to do agricultural research. And, to do that effectively requires planning. This paper will present a brief rationale for planning research, a discussion of generalized research planning process, a brief description of ARS' planning system as related to the rationale, and an outline of how technology assessment (TA) can be used in the ARS planning system.

Research Planning Rationale

Research planning is an iterative process, usually involving the scientific method: propose multiple hypotheses, propose critical experiments to disprove the hypotheses, carry out the experiments, and recycle. While the scientific method is the essence of research planning, it is only part of what is required in ARS. The agency has approximately 3,000 scientists at 175 locations, and all are developing new agricultural knowledge and technology. Questions such as what should these 3,000 scientists be proposing hypotheses about, how should their efforts be divided between various research approaches, and what is the probability of success, are also part of research planning. Of equal importance is assurance that the research is coordinated not only within ARS and other USDA agencies, but also with the agricultural experiment stations, the various agribusiness industries, and any other organizations doing agricultural research. Obviously, these concerns require much more than simple routine application of the scientific method by 3,000 individual scientists.

A simple definition of research is a two-step process in which a carefully structured question is asked and then precise scientific methods are used to find an answer. This describes the majority of ARS' research. The essence of research planning is deciding which questions to ask, and then choosing the best way to find an answer. The two are linked by scientific method. They do not help decide what to make a hypothesis about but a proposed answer to a question is a hypothesis in itself. In fact, several possible answers to a single question may result from a thorough analysis, so that multiple hypotheses may be proposed. Each hypothesis in turn suggests experiments that can be aimed at disproving a hypothesis, and the hypothesis that cannot be disproved is adopted as the "proven" answer to the question.

A special situation exists when a question is so carefully structured that the question itself points directly to an experiment. Obviously, then, no hypothesis is needed. In either case, however, our simple definition of research restricts research activities to those where an experiment is involved.

Two factors must be taken into account when selecting a question. Relevance to an objective is the first, because we seldom can afford to do research simply because it is interesting. The degree of researchability is the second concern because science at large is continually making progress and research methodology is improving. What is not researchable today may easily be tomorrow.

Relevance is a complicated matter because big questions and little questions can be asked. This can lead to big hypotheses and little hypotheses being proposed. Hypotheses that are too broad, however, have limited usefulness. When too broad, they are so general that they hypothesize nothing. Furthermore, available resources may not

permit the required experiments to be carried out. Consequently, a hierarchy of questions usually will be necessary in order to show relevance to an objective and yet allow for small, sharp questions that can be researched within experimental limitations. The situation can be visualized as a research question tree. The trunk of the tree is analogous to research objectives. The various branches of the tree represent major subdivisions of the objectives. The twigs on the branches represent the small, sharp questions that can be handled within experimental limitations.

Usually, more questions can be identified than there are resources available to handle them. Consequently, priorities need to be established. Assessing researchability is probably best done when establishing priorities. Following determination of priorities, available resources can be allocated to the highest priority questions. The scientific method can then be applied to the highest priority questions and detailed experiments planned and conducted. At the conclusion of each experiment, the results are evaluated and taken into consideration when decisions are made about which questions to take up next.

Generalized Research Process

The rationale for a generalized process for planning research is illustrated in Figure 1, using symbolic language to designate activities, decisions, and time. The process begins with the completed activity of identifying an area of research. Identification can occur as a result of a crisis, recognition of new opportunities, the reevaluation of existing programs, or an evaluation of broader programs. Usually the research area will be large, so the hierarchy of questions will be large. The major objective, therefore, should be to develop as simple a question tree as possible, so the questions isolate only unknown information and reduce redundancy. Block 2 represents the activity of developing a hierarchy of questions.

When the hierarchy of questions is large, setting priorities and allocating resources become critical activities. Even where the hierarchy is small, the same activities are required. For example, a scientist has to set priorities and allocate resources even if the resources amount to no more than his own time. So, the procedures may vary according to the size of the project, but the process is the same. After setting priorities (block 3) and allocating resources, (block 4) the scientific method is employed (block 5). The three decision blocks (6, 7, and 8) complete the overall process. A no answer or yes answer in the three blocks will determine how quickly and at what level the research process repeats itself. For example, a no answer in decision block 7 likely would mean a major shift of the selected questions and illustrates how evaluation is in fact a major part of planning.

The general process symbolized by Figure 1 shows <u>what</u> must occur if planning is to be most effective. <u>How</u> each activity is executed is not prescribed, and probably should vary depending on the size of the project. The process does identify relations that must exist between chosen procedures. The process also identifies how the two decisions discussed above are related. Selecting a carefully structured question is analogous to planning in an area, and it is executed in blocks 1 through 8. Deciding how to answer the selected question is analogous to planning an experiment, and it is executed in block 5.

ARS' Research Planning System

ARS documents its research plans at two levels. The first is a National Research Program (NRP). It is roughly equivalent to a hierarchy of questions (Block 2, Figure 1). The form is different, however, because an NRP also must meet the requirements of the USDA program structure. Briefly, each NRP is titled according to the area of research. Within that area, specific Technological Objectives (TOs) are identified. The TOs are equivalent to questions that need answering. For each TO, current technology, visualized technology, and the research approaches needed to achieve the visualized

GENERALIZED RESEARCH PLANNING PROCESS

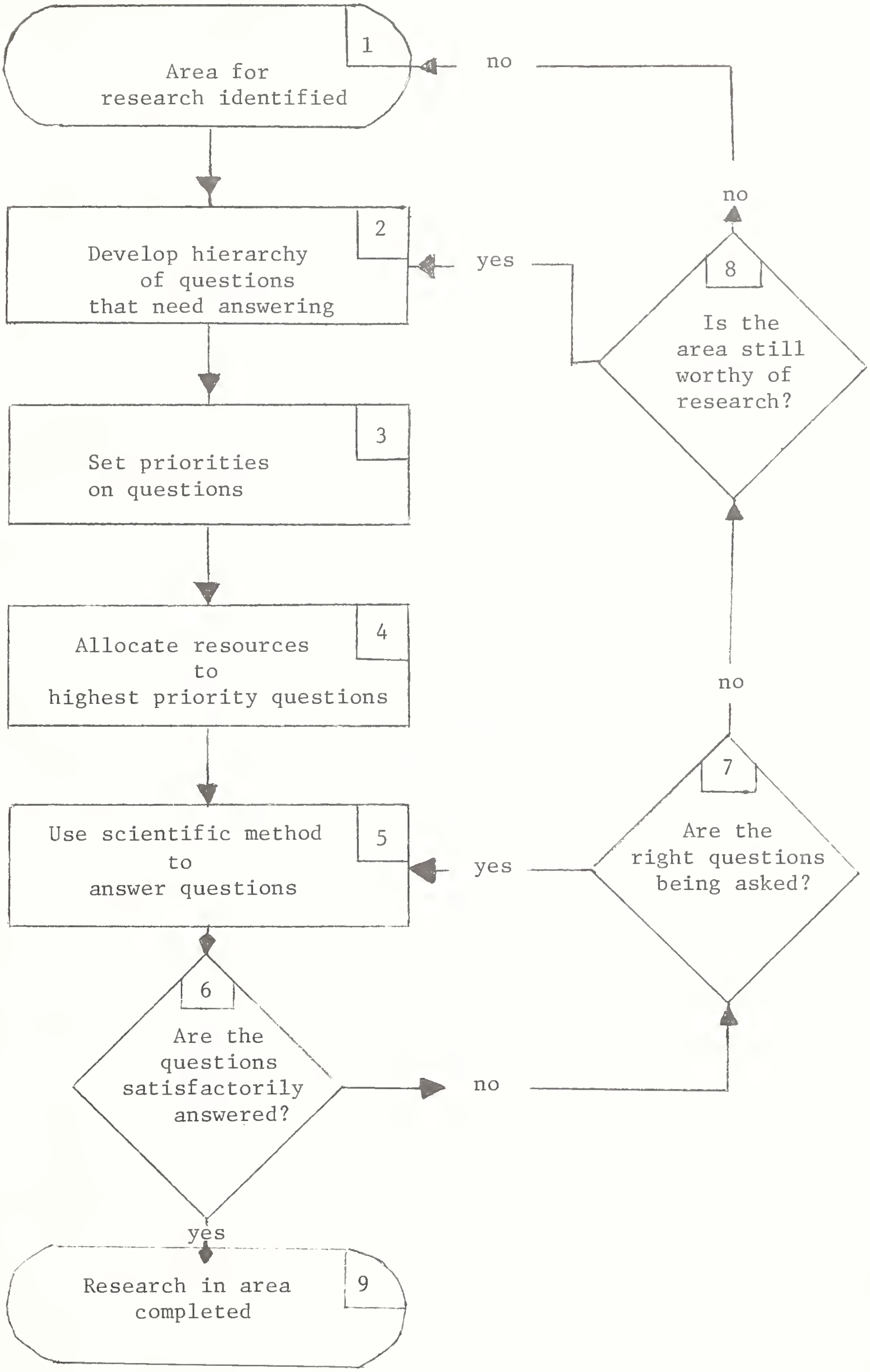

Figure 1

technology are described. Visualized technologies are a combination of what should be done and what could be done when taking into account scientific feasibility. Another key part of each TO is the consequence of a visualized technology. As related to block 2 in Figure 1, TOs are equivalent to subquestions, and research approaches are yet another level of breakdown.

The second level for documenting ARS research plans is a Current Research Information System (CRIS) unit. However, before a CRIS unit is developed, blocks 3 and 4 in Figure 1 are executed. They are done in various ways (not the least of which is the funding process) and culminates in the assignment of an NRP to one or more of the agency's 175 locations. This assignment establishes a Work Reporting Unit (WRU)--a different one for each NRP at a location. Within a WRU, scientists develop specific research projects that are documented in CRIS units. When approved, each CRIS unit establishes specific objectives that are equivalent to small sharp twig-like questions that can be handled within experimental limitations. As experiments are carried out and the results analyzed and interpreted, blocks 6, 7, and 8 in Figure 1 are executed. Depending on the answers to the decision questions, CRIS units may be revised, new ones initiated, TOs and resulting parts on NRP's revised or the whole NRP changed.

Technology Assessment

The above provides a perspective to illustrate how ARS can use technology assessment as a tool for research planning. The mission statement for ARS implies that the direct impact of its research will be on science (new knowledge) or technology (the way something is done). On the spectrum of research activities ranging from basic through applied to development, test, and evaluation, ARS focuses on the basic and applied end. However, even the basic research of the Agency is problem oriented since it is directed towards one or more visualized technologies. Thus, the word technology (a way of doing something) has a specific meaning in the Agency, and it interfaces with the Agency's research planning system in three ways. These three ways can be identified by the following questions:

1. What technology should the Agency be trying to develop?
2. What technologies are technically feasible today?
3. What are the consequences of the technically feasible technologies?

The first question is concerned with broad long range issues. Questions such as protein production by plants vs. animals; control of pests by chemical or nonchemical means; and energy intensive agriculture vs. labor intensive agriculture are examples. Answers to such questions define areas of research, and these areas are identified by titles for national research programs--block 1 in Figure 1. Currently, informal unstructured procedures are used to decide the answers to question 1 above. Undoubtedly technology assessment techniques can provide a more orderly and systematic way to make these decisions.

The second question relates to visualized technologies in the NRP's. Visualized technologies are subtechnologies of the broader technology associated with the NRP title. In fact, the visualized technologies are envisioned to be those that probably can be achieved in 10 years or less. They are projections of the results of research. They are usually extremely difficult to identify because they emphasize what technically <u>could be</u> done rather than what necessarily <u>should be</u> done. This emphasis suggests that the research scientists involved in the research are best able to clearly identify the visualized technologies. Technology assessment techniques probably have limited value in the identification process. However, identifying visualized technologies is a key step in ARS' research planning system.

The third question relates to the consequences of visualized technologies in the NRP's. Once the visualized technologies have been clearly identified, technology assessment can be used to help determine their consequences if adopted. Because of the narrower scope and likely more immediate use, the technology assessment techniques for visualized technologies may need to be different from those for the broader technologies (question 1). The consequences of visualized technologies will help decisionmakers establish priorities--block 3 in Figure 1 in the generalized research planning process.

The NRP's and the decisions that establish a WRU are the mechanism whereby ARS' research program is coordinated. Efforts of the agribusiness industry and State agricultural experiment stations are taken into account both when developing NRP's and when establishing WRU's. Since NRP's contain more research objectives than can be achieved with available resources, and since they are periodically revised, they may be viewed as a slowly moving target towards which ARS scientists aim their research.

Summary

Research planning is a continuing multi-level line and staff iterative activity in ARS. Plans are documented at two levels--national research programs and CRIS units. Technology assessment can be used as a tool in research planning to help establish the title of an NRP which is the equivalent of an area needing research. Within an NRP, technology assessment at a much lower and more specific level can be used to help determine the consequences of visualized technologies. These two uses help determine the thrust of an NRP and help to establish priorities within NRP's.

**TECHNOLOGY AND AMERICAN AGRICULTURE: A HISTORICAL VIEW

by
Wayne D. Rasmussen
Economic Research Service

In 1970, one of America's foremost agricultural scientists wrote: "Continuing development and application of technology in production of food, fiber, and forest products can supply the next generation abundantly. It can enable them to take the actions necessary to have clean air, sparkling water, and a green and pleasant world in which to live."(1)1/ Two years later, a critic of agricultural research stated: "in terms of wasted lives, depleted rural areas, choked cities, poisoned land, and maybe poisoned people, mechanization research has been a bad investment."(2)

Technology has enabled the farmers of the United States to become the most productive in the world, supplying abundant quantities of food and fiber at low costs. However, there has been neglect of some social costs of the technology.

In considering the past 200 years, it must be remembered that land for farming has generally been plentiful in America and less costly, comparatively speaking, than labor. Thus, any device or technique permitting the cultivation of more land with the same amount of labor was usually welcomed.

At the time of the American Revolution, most of the tools used on the farm differed little from those known for the previous 2,000 years. American leaders were looking for new implements and for more productive methods of farming. George Washington, for example, asked Arthur Young, British advocate of agricultural change, to secure agricultural implements for him.(3)

The interest of Thomas Jefferson in the mechanical improvement of farm tools is nearly as well known as his authorship of the Declaration of Independence. He developed a seed drill, a hemp brake, an improved threshing machine, a sidehill plow, and a design for a moldboard plow that would turn the soil efficiently. His work tended to be theoretical rather than practical, and apparently had little influence on other farmers.(4)

The most important breakthrough in farm production in the years after the Revolution occurred with the invention of the cotton gin. Upland cotton grew well throughout the South. However, the lint clung tenaciously to the seed. In 1793, Eli Whitney, a young graduate of Yale University who had accepted a teaching job in South Carolina, invented a practical machine for separating the seeds from the lint. The device dramatically changed Southern agriculture. Production of cotton increased from an estimated 10,500 bales in 1793 to 4,486,000 bales in 1861. This extensive commercial production of cotton led to the expansion of the plantation system, with its use of slave labor.(5) The dependence of the South upon a major export crop, produced largely on slave-operated plantations, set several forces in motion which led to the Civil War. Without the cotton gin, cotton growing would not have become profitable, slavery would have declined and disappeared, and the Civil War would never have taken place.

The availability of low-cost cotton, together with the new spinning and weaving machinery adopted from England, led to the rapid industrialization of

1/ Underscored numbers in parentheses refer to references listed at the end of the report.

the New England economy. The demands of the mill towns offered New England and other farmers an expanding demand for their products. This provided a stimulus to Northern farming and encouraged experiments with new tools, implements, and methods.(6)

Plowing claimed the attention of many inventors. The first patent issued for a plow went to Charles Newbold of New Jersey. His plow, except for handles and beam, was of solid cast iron. The story goes that farmers would not buy it, fearing that the iron poisoned the land and made the weeds grow. In 1814, Jethro Wood patented a cast iron plow, and improved it in 1819. The moldboard, share, and landslide were cast in three replaceable parts. Wood's plow was widely adopted.(7)

Neither the wooden nor cast iron plows were adapted to the soils of the prairies. The soil would stick to the plow instead of sliding by and turning over. In 1833, John Lane, a blacksmith at Lockport, Illinois, began fastening strips of saw steel over wooden moldboards. These plows turned furrows in the Illinois prairie loam. In 1837, another Illinois blacksmith, John Deere, began using saw steel and smooth wrought iron for shares and moldboards. He went into partnership with a businessman, Leonard Andrus, and by 1846 was producing 1,000 plows a year.(8)

Harvesting was the major operation in grain production. The mechanical reaper was probably the most significant single invention introduced into farming between 1830 and 1860. In 1833, Obed Hussey patented a practical, horse-drawn reaper. Meanwhile, Cyrus H. McCormick of Virginia had completed a machine in 1831. McCormick patented his machine in 1834. In the 20 years following, McCormick acquired a dominant position in the business. By 1851, he was making 1,000 machines a year in his Chicago plant.(9)

The success of the reaper encouraged the development and adoption of other horse-powered equipment. Some machines, the corn cultivator for example, preceded the reaper. It was in limited use as early as the 1820's. The revolving horse rake was available at about the same time. In 1837, John and Hiram Pitts patented a widely used threshing machine. A mower which was to achieve wide use was patented by W. F. Ketchum in 1844 and 1847. Other horse-powered machines developed before the Civil War included grain drills, corn shellers, hay-baling presses, cultivators of various types, and a large number of other implements.(10)

In 1849, the first mixed fertilizers were introduced in Baltimore. Twenty-eight years earlier, Edmund Ruffin, our first soil scientist, had advocated the use of lime.(11)

The agricultural magazines of the 1830's and 1840's urged that farmers adopt the new practices. They went even further in reporting that some machines had been "generally" or "universally" adopted. Their pages were filled with advertisements extolling the new devices.2/ In 1839, the U.S. Patent Office began publishing agricultural reports, advising farmers of new inventions, and distributed seeds imported from abroad. However, farmers were reluctant to change and to try new methods in spite of the urging of the Patent Office.(12)

Farmers hesitated to invest in the implements until they felt that they would pay. The Civil War stimulated the change and resulted in the first American agricultural revolution--the change from hand power to horse power. Each farmer, on the average, invested $7 in constant dollars (adjusted to reflect changes in the economy) in new machinery and equipment in 1850, $11 in 1860, $20 in 1870, and $26 in 1880. The war-induced labor shortage, high prices, and a seemingly unlimited demand encouraged farmers to spend their savings or to go into debt to acquire the labor-saving machines. And once that was done, the farmer, ready or not, found himself committed to commercial production.(13)

Two new organizations, the land-grant or agricultural colleges in each State and the USDA, had been established in 1862 to teach new practices and encourage their adoption. This was followed by the establishment of experiment stations in

2/ For example: "Iowa Farmer" Vol. 4, 1856, p. 88; "Michigan Farmer" Vol. 11, 1853, p. 258. For a different view: "Homestead" Vol. 4, February 3, 1859, p. 320.

each State in 1887. These institutions took some years to become effective, but they eventually became the primary institutions for bringing technological change to American farmers.

During the period from 1870 to 1900, farmers had to increase income to pay for the machines, but surplus production in the period kept prices low. Food was cheap, but the farmer stayed poor as the opening of new land and widespread mechanization sent floods of grain to market. He was advised to cut production, but no single farmer could influence the market. As the results of the first agricultural revolution subsided, the rate of increase in production declined, and from the turn of the century to World War I, production and consumption were in relative balance.[(14)]

Even though many farmers faced economic difficulties during 1865-1900, mechanization was almost invariably regarded as helpful. A spokesman for USDA wrote in 1899: "Mechanization contrivances have largely supplanted human labor and increased the product of agriculture, reduced the cost of production, augmented the farmer's gross income, and made his life an easier one than it was before the machine period."[(15)]

Meanwhile, new sources of power were used on farms. Steam engines, first stationary and then self-propelled, were used, particularly in the West. Their greatest use came in operating threshing machines. They proved to be too heavy and cumbersome for most other farm work. The peak in their manufacture with 10,000 machines produced came in 1913. Thereafter, production declined rapidly, as more gasoline tractors came on the market.[(16)]

The first practical, self-propelled gasoline tractor was built in 1892 by John Froelich of Iowa. He mounted a gasoline engine, built in Cincinnati on a running gear equipped with a traction arrangement of his own manufacture, and completed a 50-day threshing run with it. The Froelich was the forerunner of the John Deere tractors.[(17)]

The first business devoted exclusively to making tractors was established in Iowa City, Iowa, in 1905, by C. W. Hart and C. H. Parr. The founders had started working on internal combustion engines after they met as students at the University of Wisconsin in 1893. Their first tractor was completed in 1901. Crude as it was, it remained in operation for about 20 years. The Hart-Parr Company later became part of the Oliver Corporation. Many tractor-manufacturing companies were formed in the next decades and many failed.[(18)]

Internal combustion engine tractors were gradually adopted up to 1920. In July 1920, farm prices dropped sharply. Farmers were nearly always in, at best, a marginal economic situation during the twenties which meant that they were reluctant to convert from proven horse-drawn equipment to more costly tractor power. Nevertheless, the number of horses and mules declined rather steadily and the number of tractors increased in that decade.

Another major force for technological change came as a result of efforts to control the cotton boll weevil around 1906. A Department leader, Seaman A. Knapp, got the idea that technological practices devised to control the weevil would become effective only if a practical method was developed to directly involve farmers. He began with demonstration farms and then turned to the county agent--a college trained man who would go into the barnyard and fields with the farmers, showing them how to improve their farming. County agents became nationwide in 1914, with the Smith-Lever Act. However, as cooperative employees of the USDA, State Agricultural Colleges, and local governments, they stayed close to the farmers.[(19)]

Hybrid seed corn became commercially available in 1926 through the work of Henry A. Wallace. However, the experiments upon which it was based went all the way back to 1876, to work begun by William James Beal at the Michigan Agricultural College.[(20)] The development of nitrogen plants during World War I and again in World War II had the effect of developing a source of nitrogen fertilizer not previously available[(21)]

The first successful combine, which cuts and threshes the grain in one operation, was built in 1836 in Michigan. This was a horse-powered machine. In the mid-1880's steam engines were used as power sources for the numerous combines being manufactured

in California.[22] The gasoline engine began to replace steam for pulling the combine and operating its mechanism about 1912. Big combines powered by gasoline engines were widely available during the twenties and thirties. The development of a one-man combine powered by a two-plow tractor in 1935 was another milestone. More than a million grain combines were in use by 1956, and the 1.5 million grain binders that had been in use in the decade before World War II had virtually disappeared.[23]

A virtually complete transition to mechanization, marked by the change from animal to mechanical power, was triggered by World War II. During the thirties, the New Deal farm programs had supported income sufficiently to encourage farmers to replace some worn-out machines with current models. The rural electrification program brought a new major power source to many and eventually to nearly all, farms. However, it took World War II, with its stimulation of farm labor shortages and high prices for farm products to convince nearly all American farmers to turn to tractors and related machines.

Mechanization was one part of the second American agricultural revolution. It, together with greater use of lime and fertilizer, widespread use of cover crops and other conservation practices, irrigation whenever necessary, use of improved varieties and breeds, adoption of hybrid corn, a better balanced feeding of livestock, the more effective control of insects and disease, and the use of chemicals for such purposes as weed killers and defoliants, made up a complementary package of effective practices.

The adoption of the mechanical cotton harvester changed the lives of many people. The first device, the cotton stripper, which removed all bolls from the plant, came into widespread use in Texas in 1926. It was reasonably satisfactory only in limited areas.[24] At about the same time, John D. and Mack Rust of Texas invented a spindle picker, upon which they filed a patent in January 1928.

The spindle picker developed slowly. In 1949, less than 10 percent of the cotton crop was machine harvested but the total was at least 96 percent by 1969. In that same period, other technological developments increased average yields of upland cotton from about 300 pounds to over 500 pounds of lint per acre. Most of the human drudgery had disappeared from the cotton farms. In 1948, about 140 man-hours were required to produce a bale of cotton in the United States. In 1968, only about 25 man-hours were required. With more complete mechanization, several hundred thousand fewer workers were required to produce the crop. This brought America face-to-face with a key problem, as expressed by two authors of an article in the 1970 "Yearbook of Agriculture": "A number of these people had limited skills and limited opportunities to obtain alternative employment in other economic sectors."[25]

Mechanization of cotton production meant the virtual end of share cropping, long regarded as detrimental to the croppers, the owners, and the land itself. But there were no real alternatives within farming for the displaced share croppers.

Not long after inventing their spindle machine, the Rust brothers recognized that it would throw "75 percent of the labor population out of employment." They were unwilling to see this happen, and resorted to one plan after another to prevent it. Their ideas included adapting the machine to small farms, marketing it with restrictions on how it was used, selling it only to community farming projects organized as cooperatives, and using their profits to assist displaced cotton farmers. However, none of these proved practical, and all were swept aside with World War II and the entrance of several firms into the business of manufacturing cotton harvesters.[26]

There is at least one serious recent attempt to anticipate problems of new agricultural technology. The Economic Research Service of the USDA, North Carolina State University, and the U.S. Department of Labor, are studying the possible effects of the pending mechanization of tobacco production. Results of that study are

reported in another paper in this volume.[3/]

In this brief survey of technological change in American agriculture and its consequences, several points stand out. Farmers have made changes on a large scale primarily when a new technology has been developed and tested and when the economic climate encouraged the new adoption. The first such period in American histroy came with the Civil War, which triggered the first American agricultural revolution and the change from hand power to horse power. Similarly, the second agricultural revolution resulted from World War II with the change from horse power to the internal combustion engine and the adoption of a package of farm practices.

The first inventions which made mechanization possible often began in the shops of farmer-mechanics. But the testing, improving, and selling was done by new farm implement manufacturing concerns. Later, engineers at many of the land-grant universities and at USDA built the prototypes of new machines. The land-grant universities, agricultural experiment stations, and extension services educated American farmers so that they could adopt and use the new machines while at the same time adjusting their farm operations to the equipment and to economic conditions.

Technology has been the key to the increase in total production and the increased labor productivity in American agriculture. Since 1950, wheat yields have risen from 16.5 to 32 bushels an acre, corn from 38 to 90, soybeans from 22 to 28, and cotton yields have increased from 269 to 520 pounds an acre. Since 1950, the output per manhour in agriculture has increased at a rate of nearly 6 percent a year compared with 2.5 percent for all other industries.

The number of farms in the United States declined from 6.5 million in 1920 to 5.6 million in 1950 and 2.8 million in 1975. The drop resulted primarily from the machinery and other technology that permit a farmworker to handle larger acreages. In 1950, there were 9.9 million persons working on farms, compared with 4.3 million in 1973.(27)

The farm population has declined with the decrease in number of farms and farmworkers. This decline has been accompanied by a change in the rural social structure. Many villages and small towns, with their schools, churches, stores, and social life have declined and even disappeared. This has been offset, at least in part, by improved means of transportation, but the full significance of the changes is yet to be determined.

An important question, and one still to be both understood and solved, is what has happened to the displaced farm population. Earlier, surplus farm workers supplied some of the manpower needed to industrialize America. Since the second American agricultural revolution, many have gone to the cities, some to a very uncertain future. Others are now part of the rural poor.

A question perhaps as important is whether or not we should permit or even encourage the persistent erosion of the farm population. Mechanization has helped keep the family farm viable by making it possible to farm the acreage needed for an economically sound unit. However, the investment now needed for establishing a new farm makes it almost impossible for the young family to enter farming unless it continues on a farm already in the family. Even the established farmer finds it difficult to finance the purchase of additional land and new equipment as technological developments seem to make this necessary. This is a major problem which must be solved for the family farm to continue to be a dominant force. We cannot stop research and hope to maintain our agricultural production. As Henry A. Wallace, then Secretary of Agriculture, said in 1940, when research was under attack as

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3/ Cesal and Shugars,"The Flue-Cured Tobacco Study: Development Strategies Project." Also, see "The Flue-Cured Tobacco Industry--Changes and Adjustments," in 93d U. S. Congress, 2d Session, Senate, Committee on Agriculture and Forestry, "1975 U.S. Agricultural Outlook," pp. 295-302; Verner N. Grise, et al., "Structural Characteristics of Flue-Cured Tobacco Farms and Prospects for Harvest Mechanization," Agricultural Economic Report No. 277, January 1975.

adding to farm surpluses: "Science, of course, is not like wheat or cotton or automobiles. It cannot be overproduced.... In fact, the latest knowledge is usually the best. Moreover, knowledge grows or dies. It cannot live in cold storage. It is perishable and must be constantly renewed...."[28] We could, however, provide more direction for research, both within the experiment stations and USDA. Technological assessment of research projects before the research is carried out could provide guidelines for fund allocation.

The application of technology to American agriculture has helped give us the most productive agriculture and one of the best diets at the lowest cost of any nation in the world. Adequate food supplies for the future depend upon research and the adoption of the new technologies. I do not believe that our salvation lies in such fields as hydroponics, the use of plankton, or growing protein on petroleum, as a French research group has shown is possible. Rather, I look to agricultural research to develop higher yielding varieties of plants and animals, particularly soybeans and dryland wheat.

Together, through research, education, and the ingenuity of our farmers, we can adequately provide for our food needs for the future. We can do this with adverse side effects of new technology held to socially acceptable levels. More research and attention, however, will be needed to anticipate and estimate those side effects than heretofore given to the broad impacts of technology.

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**CONCEPTUALIZING AND MEASURING SOCIAL IMPACTS OF AGRICULTURAL TECHNOLOGY

by
Richard G. Stuby
Economic Research Service

Throughout time, two opposing philosophies have developed about technology. One, the view that technology is good, holds the upper hand today. It has been the philosophy in USDA and the land-grant college system. We have developed a powerful agricultural technology, but perhaps, as critics charge, we have been too successful.

Critics hold an opposing, and at times discomforting, philosophy that technology may not always be good; that, in fact, it has both main and side effects which are often harmful. In the extreme, they advocate the abandonment of technology and the return to a more technologically simple but more virtuous and self-fulfilling existence.

Against this backdrop has emerged the study of technology assessment, which holds that technology is a given fact of life, but must be controlled and serve some humanistic purpose. Thus, the bottom line of technology assessment is a judgment of the goodness or badness of a technology relative to the physical, psychological, and social well-being of human beings. And the criteria by which we make these normative judgments are the substance of social impact assessment. While there is no scientific method or formula for establishing these criteria (this is an issue of values), scientific methods can be brought to bear on the development and evaluation of information fed into the judgmental processes. It is this issue that I address. My approach centers around two simple questions: What is to be measured, and how do we measure it?

What Should Be Measured?

What should be measured? The question asks us to put some bounds on the relevant variables under the heading of social impacts of technology. Rather than catalog a list of variables, I'm going to address some philosophical questions which have a bearing on how such a list might be cataloged in a real social impact assessment situation.

The first is, What is the meaning of the term social? or, How do social impacts differ from other kinds of impacts? One good way to start is to say that social should not be the residue left after "economic" considerations are removed. Invidious distinctions between sociological and economic phenomena have done great injustice to social science research, and I believe they are particularly harmful to research on the impact of technology. Whether an impact is labeled social, economic, political, cultural, theological, ethical, or whatever depends on the context in which the impact occurs and not on the nature of the impact itself. But the attribution of context can lead one astray. Thus, when a technological development creates some disturbance or change in an economic context, it is called an economic impact. Given the institutional dominance of the economy in modern societies, economic impacts of technology are often the most easily perceived, identified, and labeled. However, when a technology impacts upon more than one institution, or any one other than the economic, the perception, identification, and labeling are less precise and there is a tendency for people to use a more general label and call the impact a social impact. Thus the term, social impact often means that something has impacted, but one doesn't know where.

I would suggest a different paradigm for labeling social impacts. It includes, but does not start with, institutional labels. Perhaps the best way to describe what comes to mind when someone says social impacts is to think of where the impacts occur; not primarily in terms of an institutional or academic identity, but in terms of two levels of human organization. The two levels - aggregate and structural - define both the units of observation and the units for analysis. In turn, these circumscribe separate lists of variables that measure the dependent effects of technological change.

The first set of dependent variables, the aggregate, focuses on the way technology may impact on people as aggregates of individuals. The attributes of various aggregates of individuals are quantified and recorded in the United States on a scale perhaps unmatched in any other place or time. Survey research centers, TV rating bureaus, advertising agencies, credit bureaus, employment offices, educational institutions, and churches all collect and keep records on aggregates of individuals which are used daily in some form of assessment or other.

Thus, any technology assessment process has a tremendous array of "people data" potentially available to it. Yet, given the mountain of aggregate data and the capability for mining it with multivariable statistical methods powered by large computers, why have we not been able to find simple, straightforward social indicators which can be plugged in as the dependent variables in social impact assessment?

A good part of this problem involves the idea that people do not exist only as aggregates of individuals. The whole notion of a society or culture implies that people also exist in groups, organizations, and institutions in communities distributed across regions. They represent clusters of variables which often crosscut the statistical aggregates found in the previously mentioned data sources. Each comprises what we will call here the structural components of social organization. The distinguishing variables may be referred to as structural variables. These may buffer, suppress, enhance, or otherwise alter the impacts of technology on people at the individual aggregate level. It follows, then, that while individual aggregate data are necessary to understand what happens to people, structural level data are necessary to understand how it happens.

Knowing the mechanism by which a given technology impacts on people is essential if the social impact assessment is to be used as feedback to the development or implementation of the technology. Thus, social impact assessment must consider both aggregate and structural variables if it is to be part of a viable mechanism for controlling the use and development of various technologies.

On Measuring Social Impacts

Measurement of the variables at both the aggregate and structural levels is expensive and subject to high residual error. But, that's precisely why more effort must be given to the development of valid and reliable measurements. It seems to me that we sometimes defeat this purpose by dragging along some myths imparted to us during our training. One of these myths is the idea of hard and soft or, as more frequently used, qualitative versus quantitative data. Just as I would lay to rest invidious distinctions between social and economic variables, I would lay to rest the equally invidious distinctions between qualitative and quantitative data. Not because there are not both real and semantic differences, but because emphasis on them may hinder research.

Different variables may have different mathematical properties, and one must be aware of them. But, the overworked qualitative-quantitative scheme does not even begin to cover the very real and conceptually important differences in mathematical properties. Statistical textbooks remind us that what is often called a qualitative variable may be a nominal ordinal variable and what is often called a quantitative variable may have either interval or true ratio scale properties. In analytical terms, it is more important to distinguish among ordinal, interval, and ratio properties than between qualitative and a lumped together quantitative class.

Confusion over mathematical properties of data leads social impact research astray in two ways. First, fascination with higher order variables may lead to the exclusion of many of the relevant, real world social impact variables which do not occur with an inherent interval or ratio metric. Culpability can accrue to a researcher who arbitrarily and prematurely decides that only ratio or interval measurement will be used. Despite appropriate nods to the methodology learned during graduate school, it is still too often true that favorite models dictate the perception of the problem and the selection of variables, rather than the reverse. Second, there is the obverse case in which fatalism and lack of research ingenuity lead to the repetition of traditional, lower order, less precise but academically safe measures. Despite appropriate nods to the philosophies of scientific discovery, it is still too often true that new research projects involve more tradition than imagination.

Both flaws can be fatal. Obviously, a two-pronged strategy is suggested that uses the best measurement available and includes all relevant variables, regardless of their mathematical properties. At this juncture, then, I will briefly discuss some measurement examples which illustrate the broad range of social impact measurement techniques at both the aggregate and structural levels.

Examples of Measurement

In a predator control study in process, we used two psychometric techniques to generate needed aggregate data. 1/ The first of these is called a magnitude estimation technique. We needed a ratio scale of survey respondent's like or dislike for both sheep and coyotes in order to help determine public policy regarding the use of various technologies for controlling coyotes on western sheep ranges. To determine this, we asked the question: "If a deer is worth 100 points, how many points would you give to 'blank' to show how much you liked it compared to a deer?" A list of various wild and domestic animals, including both coyotes and sheep, was used to fill in the blank so that each animal also was assigned a point value. The resulting data gave us scale scores for each respondent's attitude toward various animals compared to a single, identifiable stimulus--the deer. In turn, these scores were converted to a ratio measure of how much a respondent likes a coyote compared to a sheep--the essential datum we needed.

A second technique borrowed from the psychologists and applied in a survey research setting is a general allocation test. This is a technique for converting ordinal scales to ratio scales in a trade-off situation. One of the critical problems with social impact assessment is that there is often difficulty in reconciling human wishes, needs, or desires with reality. For example, people want both clean air and jobs. Within the context of an attitude survey there is a human tendency to favor all of the aesthetically good things (such as jobs) and disfavor all of the bad (such as polluted air). People are often unwilling to see the situation as a trade-off between some good and some bad. As a result, correlations between attitudes and actual behavior have generally been quite low. In the general allocation technique, people are asked to order their preferences for several objects or alternative courses of action. After they have ordered them, they are asked to allocate 100 points among the responses to indicate the relative value or preference for each. The sum of the responses must equal 100. As a result, what was an ordinal set of responses can now be interpreted as a ratio scale which can be used in more powerful forms of modeling and statistical analyses. Despite prior scepticism in the academic community, this technique worked successfully in the telephone survey conducted as part of the predator control project.

1/Research team members cooperating in this project are: Richard Magleby, Project Leader, ERS-NRED; Russel Gum, ERS-NRED, University of Arizona: Richard Stuby, ERS-EDD; Edwin Carpenter, University of Arizona.

Turning now to a brief example of measurement of a structural variable, let me explain the approach I am using to index the level of development in nonmetropolitan counties (5). Rural development includes a dimension that relates to the structure of human services ranging from retail outlets to school systems to health care delivery. One aspect of this service structure is the degree to which it is differentiated in the sense of having specialized functions to meet a wide array of human needs. In theory, then, a well-developed community, county, State, or region is one that has all of the necessary proliferation and specialization of services from which people can pick and choose those that best meet their needs and wants.

One way of measuring this "structural differentiation" is to seek out the key elements of the service structure of a community for forming an index. Analytically, we use a Guttman scale to do this. In the perfect Guttman scale of differentiation, a community that possesses any given key service function will also have each of the lower order functions, but none of the higher ones. Thus, the Guttman scale is based on the hierarchy of service functions in a given community or region.

We have been able to construct indexes of differentiation in several human services domains by applying Guttman techniques to County Business Pattern and Dun and Bradstreet data. These scales can be updated yearly and so the change in service structures can be monitored and fed back regularly into program evaluations, social impact assessments, and other policy related research.

Examples of Analytical Techniques

No matter what one does to improve measurement, there are still many variables relevant to social impact assessment that have only nominal or ordinal properties and these are not easily manipulated by the more familiar analytical techniques involving parametric statistics and the linear model. Recent years have seen a tremendous profusion of new wrinkles on the linear model. Dummy variables in regressions can handle some nominal categories. Discriminant function analysis allows estimates of a dependent categorical variable. Path analysis permits powerful causal modeling and one could go on with cluster analysis, factor analysis, and multiple classification analysis.

Without demeaning the importance of the above techniques, it must also be recognized, however, that the heterogeneous bag of nonparametric statistics can provide good alternatives when data problems preclude the proper use of parametric techniques. For example, in a recent study, I used a quasi-experimental design on purposive sample including four types of low-income families (3). The cell frequencies were too low to allow the use of parametric analysis of variance. Yet, a method of nonparametric analysis of variance by ranks allowed me to test the significance of differences among the four types of low income families without violating the assumptions of normality and homoscedasticity inherent in conventional analysis of variance (2). Other nonparametric developments of note include Goodman's (1) work in the partitioning of Chi-square, permitting multivariate analysis of categorical data and the host of probability models which may be particularly appropriate for predicting the effects of alternative courses of action to specified future times.

Other examples could be cited, but perhaps I have made the point that an extremely large bag of measurement and analytical techniques exist for assessing the social impacts of technology. None of these techniques are unique to social impact assessment, but more of them should be given explicit consideration in social impact research.

Expectations and Implications

What can we reasonably expect from social impact assessments? As emphasized earlier, social impact assessment can be done at two distinctly different levels and the expectations differ between them. Aggregate level analysis includes such things as attitude and opinion surveys which can provide quick feedback on the fears, desires, or

concerns that various aggregates of individuals may have over some technological issue. It also includes the use of conventional statistical data series such as those developed by the Bureau of the Census and other federal and state agencies.

While aggregate level social impact assessment can provide quick feedback into the overall technology assessment process, it usually provides an incomplete picture of the impact situation. Part of this is due to the fact that the aggregates used are seldom standardized units of observation. They shift, and fluctuate among studies, both in number and in definition. Furthermore, while the temporal nature of some aggregate variables makes them useful for sensing short-run fluctuations, it may render them useless for sensing meaningful long term trends.

Social impact assessment should also include structural level analysis. For it is in the structural realm that the impacts of technology have potential long-run, confounding, interactive and perhaps irreversible effects. Most importantly, however, the mechanisms for buffering, attenuating, altering, preventing, enhancing, or compensating for the impacts of technology lie basically within the structural components of society. It is the net result of planning, influence, pressure, or persuasion of all the diverse components within the social system that causes, influences, determines, or produces the existing state of society at any given time. Thus, structural analysis has the capability of acting not only as a simple direct feedback loop between receptor social system components and the technology-producing components, but also as a feedback loop between the social impact situations and the goal setting processes themselves. Thus, structural analyses can deal with a technology of human organization, which is an essential component of technology assessment.

Conclusions

I have sketched out some ideas in this paper which may help move us together into assessments of social impacts of agricultural technology. I have stressed the need to properly identify what we mean by social impacts in terms of where they occur, and the need to stay up to date on methodological advances in measurement and analysis. There is an additional need for us to learn to produce and package social impact assessments for timely, effective communication to the public, for it is in the arena of public decisionmaking that social impact assessment has its major justification.

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THE FLUE-CURED TOBACCO STUDY· DEVELOPMENT STRATEGIES PROJECT

by
Owen K. Shugars and Lon Cesal
Economic Research Service

In the late sixties and early seventies a number of questions were raised about changes occuring in the tobacco industry. 1/ A major research effort was organized to address the issues, and it became known as the Development Strategies Project (DSP). It is a matrix organized to investigate adjustments to change in the flue-cured tobacco industry. The title (DSP) was chosen to describe the broad scope of the research undertaken to address the range of questions associated with tobacco mechanization. The matrix comprised several subprojects with unique objectives, but each was oriented to accomplishing three central objectives:

. Determine the number and characteristics of persons likely to be displaced due to technological changes in the flue-cured tobacco industry.

. Determine the type of adjustment problems the displaced persons are likely to encounter as they seek alternative forms of employment and income.

. Prepare materials to help decisionmakers develop a strategy (combination of policies and programs) for expediting desirable changes in the flue-cured tobacco industry and abate potential adjustment problems associated with the changes.

Our approach was to evaluate prospects for technical change, project adoption of technology, characterize the resources that would be affected, project the magnitude of the effect, and analyze accompanying adjustment problems. Three ERS divisions--Commodity Economics Division, Economic Development Division, National Economic Analysis Division--the U.S. Department of Labor, and North Carolina State University are involved in the research. This paper reports major findings to date.

Study Results

An initial step was to determine the state of technology prevailing in the early seventies on farms, in auction warehouses, and in processing plants. This state was to serve as the basis for measuring change. Emphasis of the study was on measuring the effects of mechanization on labor. Expectations were that the greatest impact would occur on farms but that technical changes on farms would likely precipitate changes in markets and processing plants.

Analysis of survey data for auction warehouses and processing plants caused us to concentrate our resources on farm mechanization for several reasons: Processing plants were found to have already adopted new technology, so most of the anticipated labor force adjustment there had already occurred. Technology had changed very little in auction warehouses, but an institutional change (the market designation plan) had been implemented, so pressures for technical change were less. The size of the work force in auction warehouses was found to be relatively small (total about 8,500). Household surveys indicated very minimal overlap of individuals or families employed in harvest, marketing, and processing work.

1/ For example: "Social and Economic Issues Confronting the Tobacco Industry in the Seventies," a conference held in May 1971 at the University of Kentucky; and "Taste, Technology and the Government: The Case of Tobacco," unpublished Ph.D. dissertation of Charles K. Mann, Harvard University, 1971.

In a 1972 flue-cured tobacco farm survey, 10 different harvest systems were identified (1). These may be classified into two broad categories: conventional barn systems and bulk barn systems. Harvest labor use in 1972 averaged 9.6 hours per 100 pounds of cured leaf, and ranged from 13 hours to 2.8 hours per 100. Conventional systems were high labor users, and bulk systems were low labor users. Mechanical harvesters are used only with bulk barns, but barns may be used without the harvester. Switching from the most labor-efficient conventional system to the most labor-efficient bulk system, excluding the mechanical harvester, saves an average of about 4.5 hours per 100 pounds. Adding the harvester saves another 1.7 hours.

The profitability of bulk barns and mechanical harvesters is related to farm wage rates and farm size (tobacco production). As wage rates increase, the farm size needed to justify mechanization decreases. A linear programming framework, incorporating the structural characteristics of production units, was used to project mechanization to 1980. Constrained optimal solutions were derived for three projections, assuming wage rates would increase 50 percent relative to other prices by 1980. These projections were for a low quota output (50 percent less than 1972 production); a medium quota output (the same as the 1972 production); and a high quota output (50 percent greater than 1972 production). A fourth projection assumed no change in relative prices with medium output.

In 1972, bulk systems were used for about 8 percent and mechanical harvesters for about 1 percent of the crop. Our projections for 1980 are:

	Bulk alone	Bulk & harvester	Total
		Percent of pounds	
Low output	65	21	86
Medium output	67	22	89
High output	62	30	92
Constant relative price (medium output)	48	17	65

Under the assumption of higher wage rates for 1980, the proportion with bulk systems doesn't vary much. Of course, in absolute terms much more production is mechanized with high output.

From this analysis we conclude there are strong incentives to mechanize flue-cured tobacco harvest. Furthermore, experience since 1972 indicates our projections are about on track. Production in 1975 was 38 percent greater than it was in 1972. We estimate bulk systems were used for 38 percent of the 1975 crop (mechanical harvesters on 18 of the 38 percent) (2).

Demand for harvest labor, when compared with 1972 requirements, ranges from a reduction of 72 percent for the low output to a reduction of 23 percent for high output. In terms of job opportunities lost the range is from 266,000 for low output to 84,000 for high output over the 8-year period 1972-80. The reduction in job opportunities would be spread, though not evenly, over about 200 counties. For the most concentrated production region, the Coastal Plain of North Carolina, the reduction could average 770 harvest jobs annually per county. Minimum impact is for high output--average annual reduction of 240 per county in the Coastal Plain.

Now that we have an estimate of the numbers of people who might lose harvest work opportunities, we come to the sticky question: Who? Comparing "worker requirements" of mechanized systems with those of conventional systems expected to be replaced gives some insights into which workers could lose their jobs.

Bulk barn systems tend to employ fewer youth (under age 18), few women (18-24), and fewer older workers (over 45), than do conventional systems. Major jobs associated with conventional systems not needed with bulk systems are done by handers, hand loopers, and tying machine workers. More than 90 percent of the workers performing these tasks in 1972 were youths (under age 18) and women (age 18 and older). Mechanical harvesters will reduce the number of primers needed, and they tend to be

young and middle-aged males. Opportunities for jobs with mechanized systems such as bulk rackers, barn loaders, and barn unloaders tend to favor able-bodied males.

Although most of these jobs can be and sometimes are done by women, survey results show that in 1972 males did 80 percent of the harvest work for bulk barn systems compared with 61 percent for conventional systems. It appears also that job losses for the seasonal hired worker category would exceed that of family and regular hired workers. Seasonal hired workers did 75 percent of the handing, 74 percent of the hand looping, and 63 percent of the tying machine work in 1972. Moreover, it is likely that family and regular hired workers would have priority for jobs with mechanized systems.

Our evaluation of "who" is not yet complete. We will draw on our 1972 farm survey for labor demand information and on the North Carolina State University household survey for labor supply information. Our approach is to integrate these parts into a "displacement ranking scheme." The insights gained thus far point to youth and women as the most likely to lose harvest job opportunities.

However, discovering who will lose opportunities is only one step in evaluating implications. We must also measure the value of such losses. From the survey of household work force participation, we know that in 1972 earnings from tobacco harvest work averaged $346, and over 80 percent of the workers earned less than $500 from harvest work. Nonetheless, for three-fourths of the workers harvest earnings constituted more than 75 percent of their total earnings. We know also that harvest workers were young; the average age was 26 with over half under 18 (3).

The low average earnings from harvest work obviously are not enough to live on. If the individual worker were to lose his harvest employment, he would be adversely affected, but we have yet to determine how seriously it would affect household earnings. Earnings from harvest may be all of an individual's earning, but may represent a very small fraction of his or her family's earnings.

Conclusions

This is a very brief description of the complex setting we are trying to understand and in which we must assess tobacco harvest technology. Direct, indirect, and interdependent effects must be assessed. The implications are difficult to interpret. For example, what are the implications of lost part-time job opportunities for youth? How do we evaluate the importance of the loss of a few hundred dollars of harvest earnings?

We continue to wrestle with some of these problems. As implications of the study results are analyzed, we will begin to address the policy and program objectives of the project.

From results thus far we conclude: Flue-cured tobacco harvest mechanization is occurring and will continue to occur at a rapid rate through 1980. Experiences since 1972 indicate projections have been realistic. We are about on track notwithstanding the optimal nature of the projections. The impact on the demand for labor will depend on the level of output--substantial reduction for a low quota output, moderate for medium, and slight for high output. There is less variation in proportion of the crop mechanized for the three levels of output than one might have anticipated. This is easy to reconcile because bulk barn adoption is profitable on relatively small production units. However, adoption of the harvester varies substantially by output level.

People who will likely lose harvest job opportunities are those doing jobs associated with conventional systems that would not be found in mechanized systems. These are mostly youth and women. Mechanized systems tend to favor employment of able-bodied males because of the physical stamina required.

We are currently refining our estimates of who will lose job opportunities and attempting to evaluate the implications. If the individual worker were to lose his harvest employment, he would be adversely affected, but we have yet to determine how seriously it would affect household earnings. Moreover, we are trying to grasp the implications of lost job opportunities for youths.

The importance of the latter is perhaps illustrated by an item from the "Atlanta Constitution" of April 1, 1976: "State officials who already have recorded solid indicators of economic improvement are counting on agriculture activity to play a major role in providing summer jobs for teenagers who have had difficult tasks finding part-time work in recent years."

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ASSESSMENT OF THE FOUR-WHEEL-DRIVE TRACTOR--A PROGRESS REPORT

by
Gordon E. Rodewald
Economic Research Service

For several years the farm machinery industry magazine "Implement and Tractor" has pointed to an increase in the horsepower of tractors sold in the United States (1). As farms have become larger, farmers have demanded larger tractors to insure continued timeliness of field operations. The demand for tractor horsepower above 140 drawbar horsepower since 1970 has been met largely with 4-wheel-drive (4WD) tractors.

The movement to larger tractors poses several questions relating to the broad impacts of the new technology:

. Does the 4WD tractor add to the potential for increasing the size of farms more than conventional 2-wheel-drive or crawler tractors do?

. What impact could widespread adoption of the 4WD tractor have on such public interest factors as the demand for farm labor, tillage, soil conservation, the environment, and the numbers and size distribution of farms.

. How will the farm input industries and rural comminities be affected if there is widespread adoption of 4WD tractors as a major source of farm power?

A broad study was designed to project the impact of the 4WD tractor technology on agriculture and to assess the physical, environmental, and social consequences. We considered the net effect on farming operations, the rate of adoption, and social consequences in that order. This was the general procedure used by Schmitz and Seckler in assessing the impact of the mechanical tomato harvester (2). This paper reports some initial findings from the Pacific Northwest phase of the broader technology assessment study.

A Brief Historical Perspective

The average farm size in the United States has steadily increased since the first agricultural census was conducted in 1880. As farms have grown in size, so has the demand for larger implements and more tractor power. Farm operators try to maintain the farming operation as a one-man unit by increasing tractor and implement sizes. Until the early sixties, the demand for more tractor horsepower was met with tractors which were 2-wheel drive or track type.

Starting in the sixties, major tractor manufacturers began experimenting with 4WD tractors. The technical advantage of using four wheels to pull a load was known long before the 4WD tractor was introduced into the Northern Plains in the sixties. Massey-Harris built a 4WD model in 1930. However, the 4WD was not widely adopted even in the sixties because it was not shown to be economically advantageous to do so at that time.

Pulling with four wheels allows for greater traction efficiency, thereby permitting more effective use of available power (3). Because of this feature and the fact that relative costs of such machines recently has taken a more favorable turn, it is not surprising that demands for increased horsepower are being met with the 4WD units. During the period 1970-74, numbers of the 4WD tractor increased to over 4 percent of the total of all tractors sold.

Currently, there is no reliable indicator of the rate at which the 4WD technology is being adopted by size and type of farm. To estimate the number of adopters, it is necessary to know the number of farming operations by farm size in terms of acreage and

the rate at which the number of farming operations for each size class is changing. Projections of past growth in farming operations suggest that 57 percent of future enlargements will be on farms currently over 1,000 acres in size (4). Thus, the potential rate of adoption of 4WD tractors could be quite high because these power units can be used more effectively on farms of 1,000 acres or larger.

Associated Economies

The geographic area of this study encompasses most of Washington State's dryland farming, but the analysis is also applicable to Northern Oregon and the bordering Idaho counties. The diversity in moisture and soils allows for a variety of cropping patterns. The three rotations used in this study are representative of the area and include (1) winter wheat and summer fallow each at 50 percent of the cropland; (2) winter wheat at 75 percent and summer fallow at 25 percent; and (3) winter wheat at 42 percent, field peas at 36 percent, barley at 17 percent, and summer fallow at 5 percent of the cropland.

Several sizes of conventional 4WD tractors were analyzed. However, for unit cost comparisons we need illustrate only one size for each type of tractor. A 90 drawbar-horsepower (DBHP) conventional crawler tractor pulling a 4-bottom plow will handle 700 acres, assuming 300 hours available for plowing. A 228 DBHP 4-wheel-drive tractor using the same 4-bottom plow will handle 1,100 acres in the same time period. The cost per acre of operating the larger tractor fell below that of the smaller tractor at approximately the 900 acre mark. The economies appear to be clear: the larger tractor enables the farmer to farm approximately 400 additional acres, using the same sizes of implements 1/. The move to the larger tractor and acreage lowers the machinery cost per acre by $8.07. There is also a slight labor saving of 12 hours per season.

But, purchasing a larger tractor to use on the same size farm (700 acres) results in excess machinery capacity and significantly higher per acre costs. The potential savings in labor costs do not compensate for dollars lost in other machinery costs. Lower per acre cost could be achieved only by moving to a larger farm size. Thus, there are two reasons to increase farm size as farmers acquire excess machinery capacity: Farmers can decrease their per unit operating costs and make use of their excess labor.

The micro analysis for this study supports the conclusion it makes sense for some farmers to adopt the 4WD tractor, but only if they enlarge their farm sizes. However, the potential for adoption is sufficient to warrant further study, including an assessment of secondary and delayed consequences.

Impact of Tractor Technology on Farm Size and Imput Demand

Analysis of machinery costs on the farm suggests many operators have an opportunity to benefit by adopting the 4WD tractor. Some can benefit by adopting the tractor concurrently with increasing the size of operations. Others may have farming operations of sufficient size to warrant adoption of the tractor. The following analysis is based on both of these situations.

Using the projected number of farming operations as a means of determining future sizes and numbers of farming operations, three increases in farm operations were analyzed. Sizes studied were farms enlarging from 700 to 1,400 acres; from 1,300 to 2,400 acres; and from 2,100 to 3,600 acres. In tital, the analysis was for three rotations (discussed in the preceding section) and three enlargements. Of the 9 farm operations studies, the move to a larger farm using the 4WD tractor was economically feasible on only 3, as shown in Table 1.

The savings on each of these farms involved one man and one less tractor with associated machinery complement. However, there was not always a savings in implement

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1/ At 1,200 acres, the farmer needs to add five teeth to the spiketooth harrow.

costs because additional implement capacity may have been purchased even though no additional tractor capacity was purchased.

Using the projected number of farming operations by size of operations as a weighting factor, the aggregate impact in terms of reduced labor and machinery costs are shown in Table 2 for those farms which are projected to enlarge.

A second group of adopters are farming operations already of sufficient size to experience a cost savings with adoption. For these farming operations, three farm sizes and three rotations are analyzed. The farm sizes are 1,500 acres, 2,400 acres, and 5,700 acres, and are based on actual sizes currently being farmed. The 4WD was shown to be economically advantageous on 5 of the 9 types of farms (Table 1). There was a financial advantage as well as a labor advantage from the 4WD on all types of the largest farms (tables 1 and 2). On two types of the smallest farms, the 4WD appeared to have an economic advantage.

Table 1.--Economic feasibility of adopting 228 DBHP 4-wheel drive tractor by farm size, rotation, and potential number of adopting farms by 1985, Eastern Washington.

	Winter wheat-pea	Winter wheat-fallow	Wheat fallow
	Feasibility (potential number of adopting farms)		
Farms enlarging			
Size, 16-25" rainfall area			
629-1,304 acres	no	yes (23)	NA
1,206-2,347 acres	no	no	NA
2,066-2,587 acres	yes (3)	no	NA
Size, 12-15" rainfall area			
721-1,171 acres	NA	NA	no
1,489-2,434 acres	NA	NA	no
2,093-3,855 acres	NA	NA	yes (62)
Farms not enlarging			
Size, 16-25" rainfall area			
1,486 acres	yes (148)	yes (122)	NA
2,394 acres	no	no	NA
etc.		etc.	

The estimated aggregate amount of labor and cost savings in Eastern Washington are shown in the total row in Table 2. The potential yearly reduction in machinery operating costs is estimated to be $7.5 million if farm operators were to switch to the 4WD tractor where such a switch is economically feasible. About $1.4 million, or 18 percent of gross gain is from labor, and this represents the potential magnitude of the capital-labor substitution, assuming labor is valued at $4 per hour.

The potential aggregate amount of labor saved or displaced in Eastern Washington is an estimated 338,887 hours per year. Assuming 1,300 hours to be one man-year of labor in the study area, 338,887 hours represent a potential displacement of 260 man-years of labor. As shown in table 2, a portion (27 percent) could come from farm enlargements where in the process of enlarging, a marginal farm unit is combined with a larger unit to make up a more efficient production firm. For the 73 percent displaced from farming operations not enlarging, the result is a more direct substitution of capital for labor.

Table 2.--Potential gains associated with replacing 90 DBHP crawler with 228 DBHP 4-wheel drive tractor in Eastern Washington by 1985

	Annual reductions in -- Labor saved	Labor value 1/	Machinery operating costs	Net gain per year	Reduction in additional machinery investment (1975-85)
	1,000 hours	Million Dollars			
Farms enlarging	91	.4	1.9	1.5	3.7
Farms not enlarging	248	1.0	5.7	4.7	11.2
Total	339	1.4	7.5	6.2	14.9

1/ Labor valued at $4 per hour.

In 1969, 71 percent of the farms in the three-county area hired workers (6,831) who worked 150 days or less (5). From the data in Table 2, it is possible to conclude that the 4WD tractor could potentially displace 4 percent of the workers in the three-county area who are hired for 150 days or less over what would be displaced through farm enlargements where conventional power sources were used to make the change.

In addition to the yearly impact on labor and machinery operating cost, there is potential reduction in the aggregate demand for farm tillage implements and conventional tractors which is estimated to be $14.9 million in the study area over the 10-year period covered by the projections. The impact of this reduction is reflected in the lower machinery costs as these expenditures are written off through depreciation. Reduced expenditures of this magnitude may be significant in terms of the impact on the size and location of implement dealers.

Conclusions

The analysis supports the hypothesis that farm operators have excess machinery capacity on their farms and can and do use this excess for farm enlargement. The 4WD tractor embodies more excess capacity than conventional tractors. The results of this study suggest that the 4-wheel drive tractor technology could displace as much as 4 percent of the agricultural labor force in the study area. This decline in the demand for agricultural labor is offset by a reduction in the yearly cost of production which more than compensates for reduced payments to labor by a ratio of 4.3:1. Additional impacts would be a decline in the total demand for farm machinery and the subsequent changes in the size and number of machinery dealerships.

The results reported here are for only a segment of the total study assessing impacts of tractor technology in agriculture. Preliminary results from other areas indicate that the 4WD will have an impacts in the Great Plains and Corn Belt similar to those found in Eastern Washington. Following additional study of the primary effects, especially in the Plains, Midwest, and Mississippi Delta Region, we will assess the further impacts of the new tractor on various variables of policy or public interest in the food and fiber system and the economy.

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**A TECHNOLOGY ASSESSMENT OF THE HOG INDUSTRY

by
Ivan C. Smith, James D. Maloney, and Howard M. Gadberry
Midwest Research Institute

Midwest Research Institute has been involved in a number of technology assessments and agriculture and silviculture studies over the past several years. An assessment of integrated hog production was one of them. The National Science Foundation (NSF) funded the study.

As we understand it, the idea for this study originated with USDA. The concern was whether the hog industry likely will follow the evolutionary pattern of the broiler industry.

We broadened the scope of this study, and have attempted to determine whether industrialization through vertical integration or coordination is in the public interest and what would be the technical, social, economic, and policy impacts of these and other less revolutionary changes.

To answer this question, we analyzed the trends of this industry. We examined endogenous and exogenous forces at work on the industry's structure and practices. We identified what we feel to be the major impacts associated with various structural changes and discussed the private, legislative, judicial, and regulatory issues associated with these trends, forces, and impacts.

General Methodology

The important elements of a study such as this are: the assessment of trends of the technology; identification of future industry structures; the identification of impacts; and the identification of the various types of issues that should be addressed (private, political, judicial, regulatory, and economic).

In many ways, a study of a changing, old technology is much more complex than a study of an evolving new technology. This complexity arises in part from an inadequate technical literature which tends to focus on very narrow segments of the technology, and in part from the way in which the technological output is used in everyday life. Much of the literature used in this study was from the agricultural news media. These media--as in other current events reporting--tend to select the most newsworthy stories for publication, and contain less hard data than standard technical literature.

Bounding the study was difficult. Initially, we thought we would only assess the impacts of total integration or coordination of the industry; that is, a situation in which perhaps 100 units would produce all the hogs. We were quickly convinced that such a change in structure and practice in the next 25 to 30 years was unlikely and that placing such boundaries on the study would not result in a very useful product. NSF allowed us to broaden the scope of the study. We selected four additional industry structures that seemed to fit some reasonably probable occurrences and also assessed the impacts of these structural changes.

The five structures we selected were:

1. Total vertical integration or coordination in which 100 to 200 units would produce all the hogs and pork produced.
2. Partial vertical integration or coordination where 40 to 400 units would produce 40 percent of all pork, and independent farmers would produce the remainder.

3. Vertical coordination in which production would remain primarily with the independent producer. These producers would, however, operate under production contracts with feed firms, packers, or combinations of such parties (that is, a situation similar to that existing in the broiler industry).
4. Horizontal coordination in which farm cooperatives or associations would predominate. Cooperatives would coordinate production and marketing as they do in the dairy industry.
5. Consolidation of the industry in which a 50 percent reduction occurs in the number of producers by 1985 and an 85 percent reduction by 2000.

We also considered two specialized elements of production: corporate or cooperative farrowing operations and custom finishing.

These structures were selected on the basis of discussions with parties of interest and from the results of a survey of 105 individuals or organizations interested in this topic. Parties surveyed included farmer-hog producers, packers, feed firms, farm associations, and livestock specialists. Figure 1 on page 48 shows the projections derived from this survey. Estimates of the extent, period of occurrence and probability of occurrence based on these discussions and on our own insight are shown in Table 1.

Our study, then, developed an overview of trends not only in pork production but also in U.S. agriculture in general. This study focused on the consequences to consumers, farmers, rural communities, and to other involved parties that could result from such changes in the structure of the hog-pork industry.

Table 1.--Probability of Structural Change in the Hog Industry

Structural Change	Extent of Change	Time Period-Years	Probability
Total Vertical Integration	100%	25	<0.01
Partial Vertical Integration	40%	15-20	<0.10
Vertical Coordination through Contracting	80%	10-20	0.25
Horizontal Coordination through Cooperatives	70%	5-15	0.40
Consolidation to 100,000 Production Units	95%	15-25	0.80
Corporate Farrowing	20%	10-15	0.60
Custom Finishing	10-15%	5-10	0.50

Impact Analysis

A quasi-Delphi approach was used to identify and assign values to impacts. Panel members included about 10 in-house staff members and consultants. We also made many phone calls and personal visits to organizations and individuals who we thought might help.

A "shopping list" of potentially impacted parties and types of impacts was assembled. The panel reviewed the list and made recommendations for additions or deletions.

Each panel member then ranked the impacts as to both importance and magnitude using a ranking system of +3 to -3.

The panel members were then assembled and the assignments of impact magnitudes were negotiated with each member of the panel being allowed to present his rationale for his value. In most cases, the value ultimately assigned was the average of individually assigned values, although strong agreements prevailed in a number of instances.

At these meetings, impacts judged to be of minor significance or insignificant were deleted or combined with other impacts. We also organized the impacts and condensed them into five general categories: farmer-hog producers, rural communities, consumers, the environment, and a miscellaneous category which included a list of 23 affected parties. The panel ranked these impacted categories as to their relative importance. We did this by apportioning 100 points among 5 categories.

The product of the value and magnitude was then compiled and summed to arrive at an overall relative evaluation for each of the seven industry structures considered. These values were then normalized and expressed on a scale of -100 to +100.

Figure 2 on page 48 shows the summary of the results of the impact assessment. The accumulative impact shown on the bottom line is the impact associated with changes from the current mode of operation.

Policy Analysis

The central focus of the policy analysis was on those issues likely to affect either the direction or rate of change in the structure and operation of the livestock and meat industry. Within each policy area, issues of concern were discussed and recommendations were presented where appropriate. A range of action options were listed for consideration by officials, and the beneficial or adverse impacts were discussed. In this manner, decisionmakers could quickly obtain an overview of problem areas and issues of potential legislative interest. Choices can then be weighed in light of the probable consequences of each option, and decisionmakers could elect the course of action most aligned with the interests which each represents. We deliberately sought to expand rather than limit the options associated with each potential area of public interest and concern in the belief that this approach meets the needs of those who must make decisions affecting the future of the hog and pork industry.

Because we were faced with the prospect of preparing a comprehensive assessment, our policy analysis work would have to be comprehensive. But nine cabinet departments and over a dozen independent agencies had jurisdiction. Clearly, we could not survey all of then. There had to be some tradeoff between specific issues of concern and general policy areas. 1/ These areas of concern were selected from discussions with experts, the relevant literature, and surveys conducted during the study.

1/ The policy issues and areas were: agricultural policy (production, marketing, health, quality/labeling, welfare/cruelty); business policy (credit, finance, banking); proscriptive policy (Family Farm Act); environmental policy (air, water, solid waste, rural aesthetics); technology policy (development, transfer); tax policy (land value, inheritance).

In the detailed analysis, issues and problems were grouped into related policy areas. For each area, current practices and trends were summarized, along with the consequences expected if the existing situation and policies continue. Various alternative actions were suggested, and some of the probable effects and consequences were discussed. The listing above shows the policy areas and issues within each area.

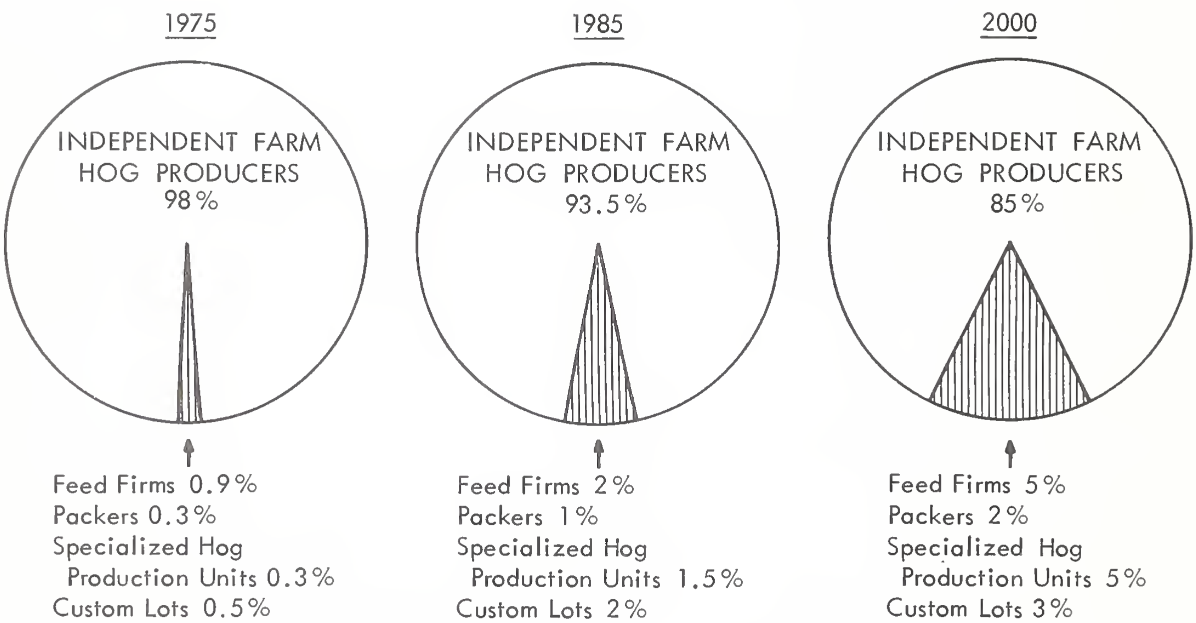
On the basis of this analysis, then, certain recommendations were made. The recommendations attempted to suggest a rational basis for policy decisionmaking, mindful of possible cross impacts with other policy areas.

Major Findings Regarding the Hog Industry

1. Large scale, fully integrated production of hogs and pork has not been adopted in the United States to a significant extent. More than 75 percent of all farmer-hog producers quit the business between 1950 and 1973, more than 98 percent of all slaughter hogs marketed are still produced by independent farmers. A handful of producers operate hog units that are very large--more than 25,000 hogs per year. These large units account for about 500,000 hogs, roughly one-half of a percent. Additionally, about 2 percent of all hogs are produced under some form of contract.
2. Major industrialization, or commercial integration of as much as 30 percent of the pork sector is judged unlikely to occur by the end of this century. There will continue to be structural changes within the pork industry--major consolidation, increased specialization, greater coordination, and larger scale--but changes are expected to be evolutionary rather than radical and disruptive.
3. The range of factors that will inhibit integration of the pork sector are unusually complex. For the next 10 or 15 years, economic considerations dominate; that is, the prospect for financial returns does not appear to justify the risks. This economic constraint could gradually be reduced through the development and adoption of new and improved hog production technology. But these changes are not likely to occur as rapidly as they did in some other agricultural sectors--eggs, broilers, vegetables, and so on.
4. The resources needed to develop large, integrated hog-pork operations are scarce, and will remain so at least through 1985. The limiting inputs include:
   a. Management skills needed to run large-scale, complex units.
   b. Capital: At least $1 million for facilities to produce 25,000 feeder pigs per year; about $600,000 for finishing facilities (plus more for environmental controls).
   c. Labor: A dependable supply, adequately trained, at affordable wages.
   d. Time: It takes 4 to 5 years to build a 3,000-sow farrowing program. First Colony Farms plans 6 to 10 years to achieve 500,000 head per year.
   e. Improved technology particularly in the areas of:
      * genetic strains offering predictable performance
      * health management and disease control
      * reduced labor requirements in farrowing
      * waste management
      * eliminating stress on animals
      * estrus control for programmed breeding

      It is not likely that the astonishing technical improvements that have been achieved since 1945 can be duplicated in the next 25 years.
5. Hog production is directly affected by many forces which originate outside the hog sector, and even outside agriculture. These external factors will play an important role in determining the nature and structure of hog farming in the future. The ways that farm policy, agricultural programs, government regulation of business, environmental standards, and rural development policies evolve over the next 25 years will play major roles in determining the extent to which intensive or large-scale hog raising is adopted in the United States. Legislation and administrative regulations which are only indirectly concerned with livestock production can easily become controlling factors affecting how rapidly changes will come.

6. While there are certain analogies between broiler production and hog production, there are enough differences that it is not probable that hog farming will undergo the turbulence associated with the rapid integration of poultry.



Ownership Distribution of Slaughter Hog Production

FIGURE 1

ASSESSMENT OF TWINNING IN BEEF CATTLE: STATUS OF THE TECHNOLOGY

by
Virden L. Harrison
Economic Research Service

In a Delphi study of emerging technologies in agriculture, it was determined that only three technologies--twinning in beef cattle, bioregulators, and photosynthesis enhancement--are expected to have unprecendented impacts in the years ahead on agricultural productivity (9) 1/. Twinning was not expected to begin its impact until the mid 1990's. It was estimated that by the year 2020, twinning by itself will have increased the total agricultural productivity index by 12 percentage points (from 168 to 180) over the projected base trend.

The length of time from introduction of the new technology to the time when adoption reaches its expected ceiling was estimated at 35 years. The rate of adoption was expected to be slow at the initial stage, increase at an exponential rate and then decline as the percent of adoption approaches a ceiling of about 50 percent, as shown in figure 1 (9).

Let's keep this study by Lu and Cline in mind as we discuss the current state of progress of natural and induced twinning in cattle.

Incidence of Natural Twinning

Rutledge (12) summarized 34 studies dating from 1840 to 1974 as to the frequency of twinning for various breeds of cattle. Table 1 gives his summary plus data from other studies. It is obvious that the natural twinning rate (less than 1 percent) for Hereford and Angus, the two predominant beef breeds in the United States, is very low. However, two other beef breeds, Charolais and Simmental, which are now used widely in crossbreeding programs have somewhat higher twinning rates (3.2 and 4.6 percent, respectively), and some dairy breeds, notably Brown Swiss, are higher still.

The incidence of multiple ovulations is considerably higher than the incidence of twins. Kidder et al. (8) found that in Holstein cows 13.10 percent had multiple ovulations, but only 1.92 percent had twins.

Several studies have shown that the incidence of twinning increases with cow age or number of calves and varies by breed. The incidence increases rapidly after the second calving, levels off and in some breeds declines after 7 to 9 calvings (for example, see figure 2).

Johansson (5) showed statistical differences in season of the year; twinning rates are higher than normal for May and October conceptions for Swedish, Danish and German cattle. He attributes the May surge in conception of twins to lush feed or "flushing" and the October surge to the animal's reaction to length of daylight.

Heritability and Repeatability

The consensus in the literature is that twinning is definitely an inheritable trait, but that the heritability--the ability of the parent to transfer the trait to their offspring--is low. For example, Erb *et al*. (3) reported a significantly higher rate of twinning for daughters of twinning cows than for daughters of cows which never

1/ Underscored numbers in parentheses refer to references listed at the end of the report.

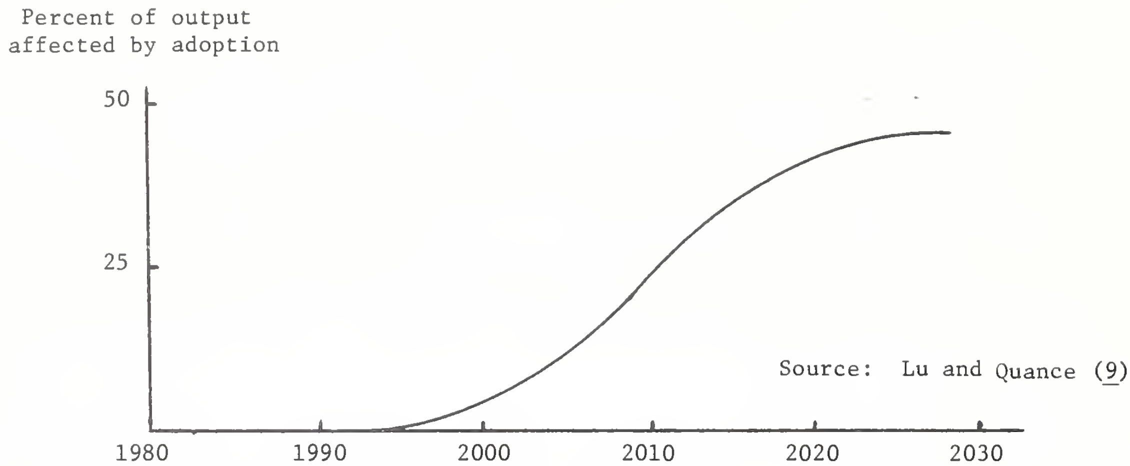


Figure 1. Adoption profile of twinning in beef cattle.

TABLE 1. FREQUENCY OF TWINNING IN CATTLE

Breed	Total number of births	Twin births Number	Twin births Percent
Dairy breeds 1/			
Holstein	25,397	857	3.4
Jersey	3,537	45	1,3
Guernsey	3,263	44	1.3
Ayrshire	889	25	2.8
Brown Swiss	305	27	8.9
Beef breeds			
Hereford 1/	8,857	35	.4
Angus 1/	1,722	19	1.1
Shorthorn 1/	1,755	12	.7
Hereford 2/	527,900	2,387	.4
Angus 2/	219,200	909	.7
Hereford 3/	34,976	-----	.7
Charolais 3/	84,007	-----	3.2
Simmental 1/	2,521	116	4.6

1/ Source: Rutledge (12). Figures are summaries of several studies.
2/ Source: Jones and Rouse, (6)
3/ Source: Johansson et al., (5) Includes USA and Swedish data for Hereford, and Swedish and French data for Charolais.

twinned (17.4 vs 12.0 percent). He estimates heritability at .11 (higher than most studies). Pfau et al. (11) reported that the incidence of twinning among the daughters of 19 bulls varied from 0 to 14.3 percent. He separated the herd into 21 cow families. Of the 21 families, 10 had no twins. In the other 11 families, the incidence of twinning varied from 2.6 to 18.0 percent, indicating that twinning is heritable.

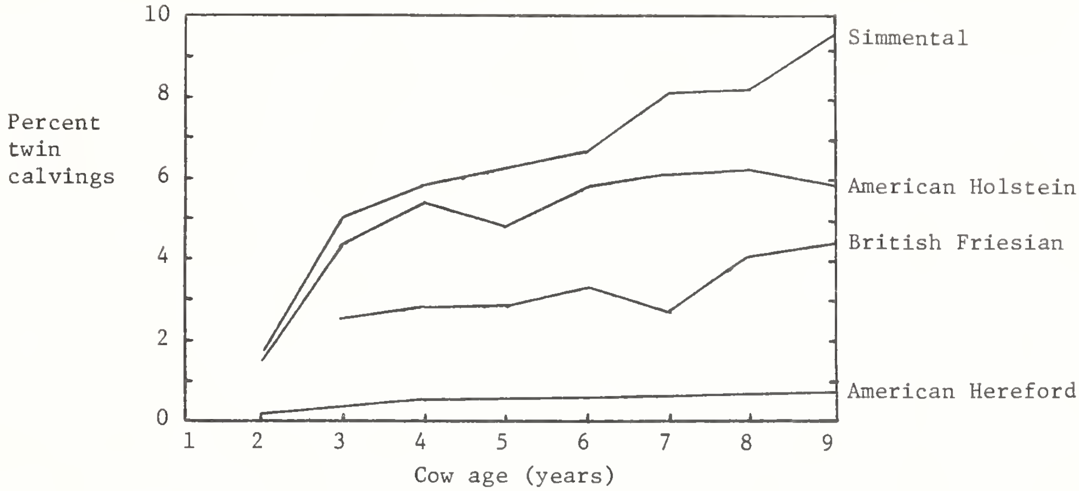


Figure 2. Effect of cow age on the incidence of twinning. Source: Rutledge (12).

For best results, therefore, selection for twinning in beef cattle should start with a breed with a high initial trinning frequency and a milk yield high enough to support two calves. The individual dams chosen for the initial stock in a selection program should have repeated records of multiple births and be mated to bulls with a high incidence of twins in the calvings of their progeny. The Simmental breed or a dairy-beef cross may be good choices for the beef breeds, being high in both twinning rate and milk yield.

The repetition of twinning for a cow increased with each set of twins. Johansson et al. (5) reported that 6.1 and 9.9 percent of Swedish Red and White and Swedish Friesian cows, respectively, had twins after the first twin birth compared to 10.8 and 15.3 percent after the second twin birth. He suggested that if 20 percent of the best progeny-tested sires were mated to cows with two or more twin births, the twinning rate could increase by about 2 percent per generation or 0.5 percent per year (slow, but positive).

Mechling and Carter (10) report an attempt by a private breeder to raise the frequency of twinning in an Angus herd. Only twin bulls were used as sires; and dams were born as twins, were daughters of twinning cows, or had twinning in their background. The experiment started in the early thirties and after 20 to 30 years, the average twinning frequency for 585 calvings between 1950-59 was only 1.71 percent. If any selection progress was made in the 20- to 30-year period, it was very slight. In theory, at least, the success should be much better than this.

Characteristics of Twins and Their Mothers

Turman et al. (13) reported that beef cows producing twins weaned an additional 333 pounds of calf compared to contemporaries weaning singles. Kay et al. (7) indicated that while twins have lighter weights at birth and 90 days, by 1 year of age weights are about the same. Others report twin weights remain smaller than singles beyond 1 year, but mature weights are the same.

About half of females born as twins are born co-twin with a male 2/; and almost all of these females are sterile freemartins. Thus, cows which twin leave, on the average, only slightly more fertile female offspring than cows which never twin, and they may leave fewer because being a twin reduces the probability of embryo and calf survival. Twin calves have a higher probability of being premature, have lighter birth and weaning weights (for example, see table 2) and three to five times higher mortality rates near the time of birth. Beef twins that survive may be weak because of lack of enough milk from the mother who is supporting two calves.

The conception rate for cows with single ovulations was found to be double that of cows with multiple ovulations (57.5 percent vs 28.6 percent). Abortion rates are three to four times higher for cows with twins. Retained placentas, cow losses and reduced longevity in the cow are higher for twin than for single births (2). Some studies indicate higher chances for difficult births for twins versus singles, but other studies report no differences. Length of calving interval is longer and difficulty in rebreeding is increased for cows with twins.

Since the earliest days, husbandmen have likely selected larger, more vigorous bulls for their herd sires. Such bulls would more likely be single-born. Thus, bulls with the twinning characteristic were automatically selected against. The same could be said for cows because of the cow problems listed above. Rutledge (12) suggests as a reason for higher incidence of twinning in dairy than beef breeds, the fact that dairy breeds are subjected to much closer scrutiny and, therefore, a higher proportion of dairy twin calves survive under the better husbandry environment. Dairy cows also have better nutrition and higher milk levels for the calves.

Inducing Twinning with Hormones

Injection of a wide variety of hormone preparations 3/ has been found successful in inducing multiple ovulation. Numerous studies of inducing multiple births by hormone treatment have been conducted. Due to lack of space, only one of these is reported. In a study by Turman *et al.* (13) of 52 Angus, Hereford and Angus-Hereford crosses which conceived at the first post-PMS estrus and subsequently calved, 29 had single calves, 12 had twins, 8 had triplets, 2 had quadruplets and 1 had quintuplets 4/. Table 2 shows data for these calves. The calf crop percentage weaned from the total number (81) of cows treated was 109 percent. No calving losses were suffered for the twin births, but death losses of triplets, quads and quints were 54 percent. Half of the cows producing multiple births had retained placentas but this did not appear to be associated with delayed rebreeding. All females with at least 1 male littermate were freemartins. Only the multiple birth calves were creep fed, which probably biases their weight figures in table 2; still, the calves born as singles were 64 pounds heavier at 205 days. Despite reduced weaning weights per calf, twinning cows weaned over 300 pounds more calf than those with singles. Furthermore, average daily gains in the feedlot did not differ significantly for single or multiple birth calves.

Inducing Twinning with Embryo Transfer

Probably the area which will speed a twinning technology along the fastest is embryo transfer. Varying degrees of success have been apparent in transferring eggs from one cow to another. Gordon (4) reports pregnancy rates as high as 91 percent for surgical transfers and 25 percent for nonsurgical transfers. (This success rate is not common, however.)

Multiple fertilized eggs are currently obtained from a donor female by hormonal induction of superovulation, but this will probably be replaced by a procedure in which eggs are taken directly from cattle ovaries and fertilized *in vitro* (in the test tube). Though commercial egg transfer organizations report an average of fewer than 4 "transferable" eggs per donor, it is justifiable to think in terms of 10-12 fertilized eggs per animal treated (4).

2/Erb *et al.* (2) reports sex ratios of 336 twin calvings as 32 percent male-male, 46 percent male-female and 22 percent female-female.

3/ Pregnant mare serum gonadotropin (PMS) and human chorionic gonadotropin (HCG) are two common hormone preparations.

4/ This study achieved higher rates of multiple births and fewer death losses in twins than most studies.

TABLE 2. CHARACTERISTICS OF CALVES BORN AS SINGLES OR MULTIPLE SETS FROM COWS SUPEROVULATED WITH PMS AND HCG

	Calves per birth				
	1	2	3	4	5
Number of sets (52) 1/	29	12	8	2	1
Gestation length (days)	280.8[a]	277.4[b]	269.2[c]	262.5[c]	258.0[c]
Birth weight (lb)					
Male	83.1[a]	59.7[b]	46.1[c]	38.6[c]	30.4[c]
Female	83.3[a]	66.1[b]	46.3[c]	35.3[c]	29.1[c]
Number calves weaned	28	23	12	3	2
205-day weight (adjusted) lb	462[a]	398[b]	349[c]	349[c]	316[c]
A.D.G. in feedlot lb/day					
Male	2.76[a]	2.62[a]	2.76[a]	2.62[a]	2.07[a]
Female	2.47[a]	2.60[a]	2.45[a]	2.36[a]	2.20[a]

1/ Number of cows conceiving at the first post PMS estrus that calved. Nineteen additional cows conceived at a subsequent estrus and ten failed to conceive.

a,b,c Values within rows with different superscripts are significantly different (P<.05).

Source: Turman et al., (13, p. 966).

Currently, most fertilized eggs are obtained from heifers bred just prior to being slaughtered. This technique provides a practically unlimited source of eggs for transfer pruposes. And within the last few years, some success has been attained in freezing for storage both cattle and sheep eggs (4, p. 28).

In inducing twinning by the egg transfer method, the two main approaches are (1) transferring a single fertilized egg to a bred recipient (preferably to the non-pregnant uterine horn) and (2) transferring two fertilized eggs to an unbred recipient cow. The first method has attained the greatest success because survival rate is substantially higher.

Advantages of twin induction by egg transfer over natural twinning include: (1) one fertilized egg in each horn of the uterus has a higher probability of survival than two eggs in one horn; (2) it is possible to prepare the cow for twinning by additional feed and attention during pregnancy and parturition; and (3) twinning can be confined to those cows which have the constitution and ability to deal with two calves.

It appears that we now have the technology for induction of twins on the farm through nonsurgical egg transfer. The success rate, at present, is low and the technique needs to increasingly refined, but it appears that most of the major problems have been worked out. If twins find favor with farmers, the day is not far off when the artificial breeding technician will be called upon to implant a second fertilized egg in the uterus of a cow he has bred a few days before. Three areas important to a twinning technology where improvement is slow but progressing are in intermediate and long term storage of ova, in controlling the sex of the twins to prevent sterile freemartins (less important for beef than dairy cattle), and in maintenance of pregnancy after conception (important for single births as well).

Studies Needed Under a Twinning Technology

We have not until now conceived of a twinning technology in cattle. With this technology on the horizon, we will have to expand research to determine production

management questions such as (1) How do nutrient requirements differ for cows pregnant or lactating with twins? (2) What milk level will be required to support twins? (3) What precautions are needed at calving time? (4) How should the twins, born smaller than singles, be managed and supplemented? (5) What growth rates, carcass characteristics and breeding characteristics can be expected of calves born as twins? (6) What does a twinning technology mean in terms of organization of the livestock industry, supply of beef, demand for feed, returns to producers and meat price to consumers.

One important consideration regards the weight loss of the cow while nursing twins and the associated reduced ability to rebreed on schedule. A large factor involved is the quality of forage available to the cow. In the lush Southeastern pastures, she would have less weight loss while nursing twins and, therefore, less difficulty in rebreeding. But in the West and Southwest, it is likely that grain supplementation for both the cow and calf, as well as early weaning, may be required under a twinning technology. Development of production systems for managing a twinning technology is needed to help alleviate possible problems.

The potential for a twinning technology to cause substantial changes in the food and feed economy of the nation is great. Biological processes involved with twinning are being studied world-wide; and with the breakthroughs that have occurred in the last few years, particularly in the area of embryo transfer, this technology may generate an even increased surge in public and private research.

Conclusions

Selection for higher natural twinning rates can indeed usher in a twinning technology, but at a very slow pace. Hormone induction of twinning has proved successful, but difficult to control. In this author's opinion, the area of greatest potential for the ushering in of a twinning technology is through nonsurgical embryo transfer. It appears that embryo transfer can be accomplished now, successfully and inexpensively, without the need for surgery in the recipient cow, and techniques are currently being developed to improve the success rate.

At least three areas of technological development are rapidly progressing and have the potential to complement each other to result in a technological "quantum jump" or unprecedented impact on the livestock industry. These are (1) nonsurgical embryo transfer, (2) artificial insemination, and (3) sex control. Through artificial insemination, the overall quality of a herd can be improved and specific traits can be easily selected for by a broad choice among sires. But to date, only a small share of beef producers use artificial insemination, because under normal range conditions use of bulls seems most profitable. But if embryo transfer, sex control and improvement of the herd through artificial insemination are all commercially available to producers, many may abruptly shift their production strategies, adopt all three technologies, and improve their herds substantially in the process. The resulting impact on every facet of the livestock industry would be substantial. And it looks like the date for the initial effects of twinning on the cattle industry may be 5 to 10 years closer than the mid 1990's projected by the Lu and Quance study (9) reported at the beginning of this paper.

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**LOCAL RURAL COMMUNITY IMPACTS OF COAL MINING IN THE NORTHERN GREAT PLAINS--A PROGRESS REPORT

by
Lloyd Bender
Economic Research Service

The Economic Research Service (ERS), in cooperation with the Environmental Protection Agency (EPA) and several universities, has initiated a research project entitled "Economic, Social, and Cultural Consequences of Coal and Oil Shale Development." An objective of this project is to assess the community impacts of resource development. The specific research objectives are to develop and test methods for estimating population, employment, income, and fiscal changes in localities affected by coal development.

Coal prices in the nation rose from $6.33 per ton in 1970 to $15 per ton in 1974. 1/ One consequence of this price rise is intensified mining of the low sulfur coal located in the Northern Great Plains.

The Fort Union Region of Wyoming, Montana, and North Dakota contains about 48 percent of the Nation's mineable coal resources. This region of the Northern Great Plains is composed mainly of sparsely settled agricultural communities. Total population was 444,000 in 1974. In general, total population of the region has grown slowly over the last 34 years. Small towns have tended to remain stable while cities increased and farm population declined. As of 1970, American Indians comprised only 3.4 percent of total population, but they tend to be concentrated in only a few counties within the coal region.

The Northern Great Plains' problems have long been characterized by "the social cost of space;" that is, the sparse settlement patterns do not support adequate community services. Coal development will cause rapid growth of many small communities. However, as indicated in this paper, the envisioned growth resulting from coal mining developments could generate "growing pains" that could more than offset the benefits of increased population. Many communities are taking actions to forestall development. Coal development is being retarded through the use of taxation, zoning, subdivision regulations, siting authorities and water rights laws. 2/ The pragmatic alternative to slow development is to compensate those who bear impact costs. Studies of community impacts of technology such as this one could provide information about who bears the costs, as well as who benefits, in the local areas.

The Conceptual Basis for Local Community Impact Assessment

The timing of the anticipated benefit and cost streams of coal conversion projects create much of the apprehension of communities about development. A general hypothesis about the benefit and cost streams is depicted in figure 1. The construction phase of a project uses large amounts of imported manpower. Manpower requirements during construction are as high as 200 for a mine, 1,500 for a generation plant, and 3,000 for a

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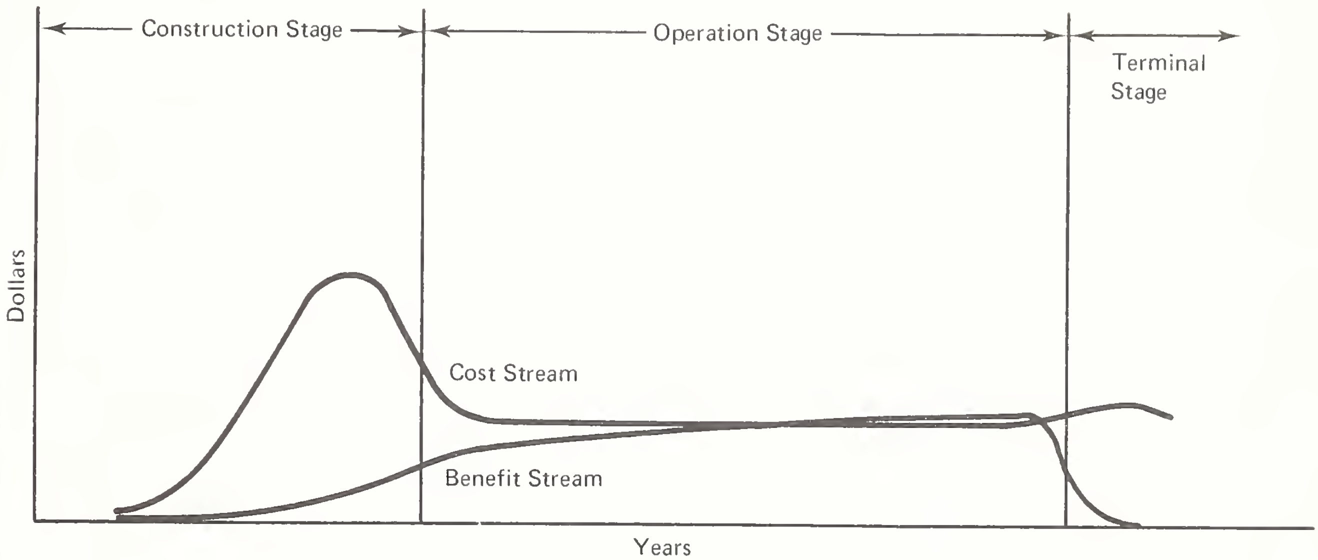
1/ U.S. Bureau of Mines' "Minerals Yearbook" and "Commodity Data Summary," 1975.
2/ A new generation of local institutions for controlling population growth by communities is emerging. See Old West Regional Commission, "Responding to Rapid Population Growth" (Vol. 1 of 6 prepared by Kutak, Rock, Cohen, Campbell, Garfinkle and Woodward), Sept. 1974.

Figure 1
Idealized Costs and Benefits to a Community of Coal Mining Development



gasification plant. The length of construction may be 2 years for a mine, and 3 to 5 years for conversion plants. The manpower for operation of these facilities may be no more than half that needed for construction, and the tax revenues necessary to cover community costs may lag several years. Finally, there is a termination phase which can imply continued costs such as any remaining public indebtedness covered by a reduced tax base, reclamation costs, or the cost of resource entropy. The exhaustion of coal resources locally, eventually will lead to a relocation of coal projects to other communities.

The timing of the cost stream influences who bears the costs. It is the indigenous populations (those who typically initiate and maintain actions forestalling development) who bear the brunt of the front-end costs, and the costs when the project is terminated. The transient construction crews and their families do suffer if community services are inadequate. But, by choosing to move into an impacted community, they reveal an expected increase in their welfare. Inadequate schooling for transient children is not a loss to the permanent community, although it is a loss to the nation.

Two distinct types of community impact costs are involved. One consists of the costs associated with a rapid adjustment of the public and private sectors of a community. They are likely most evident in the construction and termination phases of a project's life. These major adjustment costs are costs of contingency planning due to uncertainty of the coal mining operations, local wage inflation, jurisdictional spillovers or externalities, and costs of indivisibilities of components of community services. These costs are not included in the planned assessment.

The second set of costs are those which emerge as infrastructure requirements for an expanding population. They include expenditures for community services, any decline in the quality of services, and any social disruption caused. These costs typically are compared by local public officials to the tax revenues flowing to the communities. The correspond roughly to conditions during the operating phase of the project as illustrated in figure 1. These are the costs included in the planned coal development impact assessment.

Conceptualization of Community Infrastructure Impacts

Estimates of employment, population, income, tax revenue flows, and expenditures for local economies are the basic building blocks for assessing community infrastructure requirements. The basic elements of the conceptual model are presented in figure 2. Construction of a major facility in a given location requires a basic operating work force (see upper left corner of diagraph). In addition to the basic operating work force, an indirect demand for labor will arise for supplying the industry with inputs and marketing services. Finally, an induced effect is felt in the community as all workers spend their paychecks for consumer goods and services. Thus, the total labor demand due to the facility can be much larger than indicated by the size of the operation work crews.

New labor demands will attract people to the community. Wage levels will increase to the levels necessary to attract and maintain the supply of labor for the basic, indirect, and induced requirements resulting from the facility. Part of the added labor will come from increased particiaption of the communities' population in the work force. The greater part of the new labor force needs will be met by a change in migration flows. Higher wage levels in a community will reduce the levels of outmigration and, at the same time, increase the level of inmigration.

The final population change in a community (given labor demand and supply) depends upon settlement patterns and the labor commuting range. Workers may live in adjacent jurisdictions. Thus, community impacts extend well beyond the boundaries of jurisdictions containing the new coal mining developments.

The additional community infrastructure to support an expanding population varies directly with the size of the community. Large cities can absorb a new industry because the new requirements are marginal and may be spread among several jurisdictions. But small rural towns likely will have to add new service infrastructure about proportionate to the population change.

A comparison of community infrastructure requirements (both capital outlays and operating costs) and revenue flows gives the net fiscal impact through time (figure 2). Revenue flows originate from the new industrial base, and from the new population and its spending for consumption. Revenue institutions in Northern Great Plains are designed to accommodate stable communities. They are not designed for rapid decline or rapid growth communities.

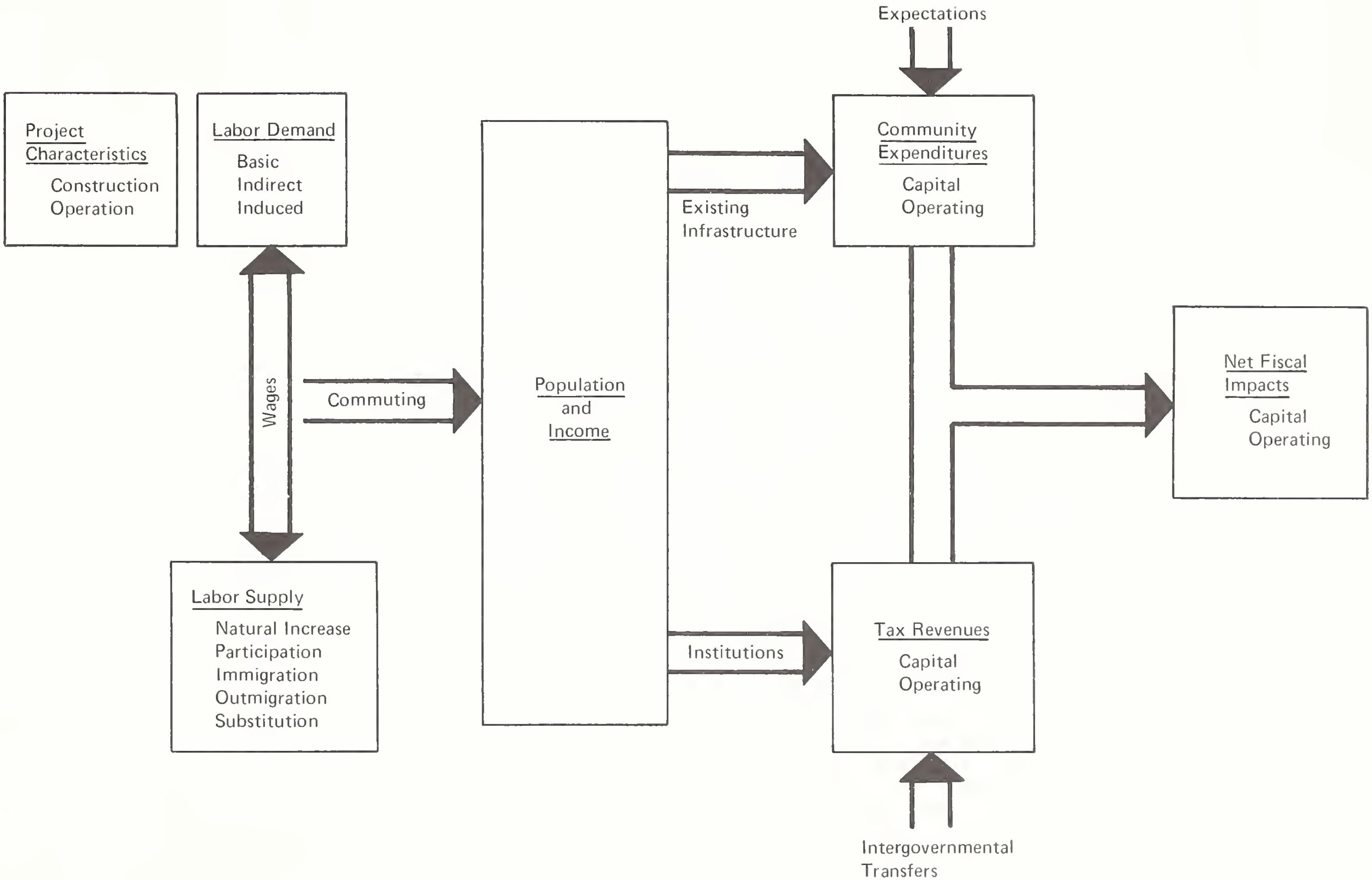
Research Progress and Plans

Results to date are based upon less than one year's activity. Progress is evident in three areas: estimating secondary employment, demonstrating the effect of local economic conditions on migration flows, and outlining tax revenue flows. The following represents a brief description of procedures, findings, and next phase of analysis.

Employment multipliers have been demonstrated to be different for each community. 3/ The amount of indirect and induced employment generated in a community (county) is a function of the type of industry, the size of the industry, its location in relation to major service centers, economic activity in adjoining counties, and income. The multipliers apply to the operation phase of a industry under normal Northern Great Plains' conditions.

3/ Not all findings have been published. For a review of prior analyses see Lloyd D. Bender, "Predicting Employment in Four Regions of the Western United States," USDA Technical Bulletin 1529, Nov. 1975; and Lloyd Bender and Robert I. Coltrane, "Ancillary Employment Multiplier for the Northern Great Plains," Proceedings of the Western Agricultural Economics Association, Jan. 1973.

Figure 2
Relations Among Elements of Local Impacts of Coal Mining Development



Data necessary to estimate the employment multipliers include the size of the operating work force and the location of the facility. Annual employment data published by the Bureau of Economic Analysis, Department of Commerce will be used in updating the data base. The procedure will include ordinary least squares on cross section and time series data (including distributive lags) for coal counties.

The migration analysis thus far as shown in- and outmigration to be a function of local economic conditions as well as economic conditions in other locations. 4/ Only census data for the 1965 to 1970 period for state economic areas are available for analysis. One analysis of short distance migration used only data of gross migration flows within the Northern Great Plains region. Both employment and wage changes in the origin and destination areas are shown to be significant in addition to other variables reflecting distance, town sizes, age and past migration. This analysis reflects short distance migration and can be used to estimate the number and source of migrants within the region responding to changing employment and wages due to a new facility.

The remaining migration is that from long distances. This analysis traces the effect of local economic conditions (and conditions at the distant location) on gross outmigration from, and gross immigration to, a state economic area within the region to each of the contiguous 48 States outside the region. Results show outmigration to distant locations to be a function of economic and social conditions in a consistent and logical manner. But the immigration from distant places do not show the same consistency in relation to economic variables.

The initial migration analyses are to be extended by recognizing the interdependence between wages, employment, and migration. Migration influences, and, in turn, is influenced by wages. This interdependence suggests that ordinary least squares single equation models may yield biased estimates. A three-stage least squares approach to the analysis is expected to be used in the second stage of this research because of the simultaneity problem.

The research on taxes identifies the State and local revenue flows resulting from a new facility. Revenue effects due to the basic activity and the indirect and induced activities can be traced to where it goes. The discrepancies between the expenditures of local governments which are impacted and the revenue flowing to them can be identified. These data show the incidence of benefits in relation to costs. They also can lead to evaluations of optimum tax systems for rapid growth communities. The tax analysis consists of a compilation of the details of each tax system in the region. An arithmetic procedure for calculating tax revenues is now being tested. Preliminary results indicate local governments are likely to experience wide disparities between revenue flows and impact expenditures.

We anticipate initiating work relating cost of selected community services to the size of town and county. These can be adjusted for local wage changes. From these data, the change in capital and operating costs for additional community services can be anticipated. It is possible, although unlikely, that excess capacity in existin; infrastructure can absorb some of the new service requirements.

4/ Initial results are contained in Eugene P. Lewis and Lloyd D. Bender, "Employment, Migration, and Income Relationships in the Northern Great Plains," discussion papper, Department of Agricultural Economics and Economics, Montana State University, Bozeman, June 1976.

USDA EVALUATION OF BOLL WEEVIL CONTROL TECHNOLOGY

by
Velmar W. Davis
Economic Research Service

The boll weevil arrived in the United States from Mexico about 1892. By 1927, it had populated 14 of the 17 cotton-producing States. Since its arrival, its offspring have eaten away at growers' cotton and their income. Estimated yield losses and weevil control costs now total more than $250 million annually. 1/

While the current losses to the boll weevil are significant, the real concern is the fear of increased losses if effective insecticides are lost either through regulatory restrictions or by the boll weevil becoming resistant to the chemicals used. Additionally, the application of early season insecticides to control boll weevil destroys the natural predators of the tobacco budworm, boll worm, and other insects and thus tends to generate the need for additional insecticides.

With support from the Office of Management and Budget (OMB) and expected special appropriations from Congress, the USDA has approved an action plan to evaluate alternative boll weevil control technology. The USDA plan is a major interagency and interdisciplinary effort that may cost (USDA, States, and growers) as much as $50 million over a three-year period to conduct large area eradication and optimum pest management demonstration trials and evaluations.

The overall objective of the evaluation is to provide information to the Secretary of Agriculture, Congress, and cotton producers to decide whether to implement a beltwide boll weevil eradication program, support a beltwide optimum pest management program that can maintain the boll weevil population below economic damage levels, or continue with current practices.

The following discussion is limited to a brief description and preliminary plans for evaluation of three packages of boll weevil control technology:

a. current practices,
b. eradication,
c. optimum pest management.

Boll Weevil Control Technologies

Current Practices 2/

Today, the majority of farmers protect their cotton crop from the boll weevil almost exclusively by repeated in-season applications of insecticides to the fruiting cotton plant. These insecticide applications limit population buildup until after yield losses to the current season's crop is unlikely or would be insignificant. This strategy assures a late season population buildup and a perpetuation of the cycle.

1/ "Boll Weevil Losses: Value and Location of Losses Caused by the Boll Weevil", National Cotton Council in Cooperation with State Extension Specialist, June 1974.
2/ Daum, Richard, "The Boll Weevil--A Preliminary Evaluation of Three Alternative Federally Supported Programs," unpublished report, July 1974

Cotton farmers have the option of drastically reducing boll weevil population through diapause control. However, for this approach to be effective, 100 percent of the farmers in the area must participate. The larger the area of participating farmers, the better.

The boll weevil survives the winter as a diapausing adult. Most adults must feed on fruiting forms from 7 to 10 days up to 3 weeks to obtain diapause. Thus, many weevils obtain diapause soon after the end of the regular in-season control program but before the food supply is destroyed. At this time, the proper application of organphosphate insecticides, defoliation and stalk destruction may reduce overwintering weevils as much as 90 percent--if all farmers in the area participate.

Resistance to the chlorinated hydrocarbon insecticides and restrictions on insecticide usage has reduced the types of insecticides available for boll weevil to the phosphates. If the boll weevil were to develop resistance to the available phosphates or if the available phosphate insecticides were to be lost through a regulatory action, cotton production could become uneconomical in many areas.

Eradication 3/

In 1969, a special committee appointed by the National Cotton Council (NCC) reviewed the available pest control technology and concluded that it would be possible to eradicate the boll weevil from the United States but that a pilot eradication trial would be required to adequately demonstrate feasibility and operational capability. The resulting 2-year experiment, 1971-73, was conducted cooperatively with state and federal research, extension, and regulatory agencies. The test site selected in Mississippi represented ideal conditions for boll weevil development and survival as well as conditions that would make program operations difficult to execute. On the basis of this test and continued research the eradication of the boll weevil from the United States with ecologically acceptable techniques was considered technically and operationally feasible.

However, beginning in January 1977, a second eradication trial is planned in North and South Carolina and Virginia to further test the ability to eradicate the boll weevil. The eradication trial area consists of about 30,000 acres of cotton. The technology to be used in the proposed program follows:

1. In-season control with insecticides recommended by appropriate States.
2. Defoliation/Dessication. All cotton will be defoliated or dessicated to hasten harvest and to reduce boll weevil food and breeding sites.
3. Diapause control insecticide treatment will be initiated following termination of the cotton crops. These treatments will be continued until stalk destruction, either by mechanical means or by frost.
4. Traps - Phermone baited traps will be located around every cotton field at the rate of one for every half-acre during the growing and harvesting season. Fewer traps will be maintained for survey purposes during fall and winter.
5. Trap crops. The growing season of the trial area is too short to permit planting of specific trap crops. The periphery of the field adjacent to boll weevil hibernation quarters will be baited with pheromone to aggregate the weevil. These areas will be treated regularly with pesticides by ground equipment in the early season.
6. Release of sterile insects. Sterile insects will be released at the rate of 50-100/acre/week over the entire cotton acreage beginning in June of the second year and continuing until stalk destruction in the fall.
7. Regulatory. Authority for access and entry to execute program components must be assured for 100 percent of the cotton acreage in the eradication zone.

3/ USDA Action Plan for Boll Weevil Eradication Trial, February 1976.

Although the basic technology for boll weevil eradication exists, some of the technology needs to be improved. Some examples of further research needs include:

1. Mechanization of mass rearing procedures and handling of sterile boll weevils for release in the field to reduce the costs and produce a higher quality sterile insect.
2. Evaluate the several methods of sterilization to determine the best one for use in the program.
3. Evaluate available trap types in order to select the most economical and effective ones for program use.
4. Further evaluate the experimental compounds, including Dimilin, to determine if other suppression measures could be integrated with the current control measures to be used in the program.

Optimum Pest Management 4/

One of the concerns regarding the results of the Mississippi eradication trial in 1972 was that there was no valid basis for comparison with alternative boll weevil control technology. Thus, an optimum pest management trial is also planned beginning in January 1977 to run concurrently with the eradication trial to develop data for comparison of alternatives.

Federally supported pest management projects have been underway in the cotton belt since 1972. The overall objective of integrated pest management is to promote the use of cultural, biological, and chemical pest control methods that are economically and environmentally sound. The objective of the optimum pest management trial is to establish that boll weevil and other economic pests can be maintained below economic damage levels through the use of integrated pest control techniques and by voluntary participation of growers in a community wide program. Although the site has not been choosen, the trial will be conducted in one or more counties, involving an area of 25,000 acres of cotton.

The program will be carried out by the State Cooperative Extension Service. Growers will be expected to pay all costs related to usual scouting of fields and will carry out at their cost, in-season control, stalk destruction, and other production practices associated with good cotton production. USDA through cooperative agreement with the State CES will pay for the chemicals used in up to four fall diapause control applications and/or pin-head square applications if needed. The payments for chemical diapause control and/or pin-head square application will stipulate that growers will comply with all stalk destruction and other pest management recommendations in order to qualify for payment. By this method it is expected that nearly 100 percent grower participation can be obtained in the demonstration program.

Evaluation 5/

Plans for evaluation of each of three packages of boll weevil control technologies are preliminary. Eradication and optimum pest management control technologies will be evaluated through the use of large area trials and the results extrapolated for beltwide implications. The study areas will consist of about 30,000 acres of cotton in North Carolina and Virginia (eradication study program) and up to 25,000 acres in the optimum pest management demonstration area. A control group of cotton producers will be identified for each of the programs to represent current control practices. Data will also be collected from a sample of growers throughout the cotton belt to more accurately characterize current practices and to facilitate beltwide extrapolation of technologies.

4/ USDA Action Plan for Optimum Pest Management Demonstration, February 1976.
5/ USDA Action Plan for Evaluation of Boll Weevil Control Programs, February 1976.

Each trial area and control group will be monitored annually for costs and benefits and control effectiveness to provide a historical basis for comparison and to enable the Secretary of Agriculture to decide at the end of each year whether to continue the large area test trials. At the conclusion of the three-year trials, a final evaluation will determine the feasibility of implementing a beltwide eradication or an optimum pest management program.

The analysis will consist of three separate evaluations--economic, biological and environmental--and an overall examination of tradeoffs. ERS is the lead agency for the economic and overall program evaluations. ARS and APHIS are responsible for the biological and environmental evaluations, respectively.

Economic Evaluation

The economic evaluation will include:

1. Costs of conducting alternative programs:
    a. Overhead (research, development, and so forth).
    b. Direct (trap crops, scouting, rearing facilities, insect release operations, and so forth).
    c. Cost sharing (public vs. private).
    d. Costs for continuing monitoring, quarantine.
    e. Time dimension.
        -- Costs 1st, 2nd, 3rd year.
        -- Consider costs and benefits over an extended time period.
2. Impacts on cotton producers. Changes in:
    a. Structure: size of farm, cotton acreage, enterprise combinations.
    b. Pest control practices and costs, and other production costs.
    c. Control of other pests.
    d. Cotton yield and quality.
    e. Cotton price and growers net income.
3. Effects on cotton industry. Changes in:
    a. Demand and prices for cotton.
    b. Competitive advantage of cotton including regional shifts to other crops.
    c. Aggregate acreage and production.
    d. Trade and exports implications.
4. Secondary effects.
    a. Local service industries, gins, custom applicators, pest management services, pesticide suppliers, transportation and warehousing, and so forth.
    b. Manufacturing: cotton versus synthetic fibers.
    c. Impact on Federal farm program costs: (targets prices, and so forth).

Biological Evaluation

Data collected by program operations personnel will be used for day-to-day evaluation in order to execute the program effectively. Also, these data will be made available to the biological evaluation team for further appraisal and for integration with the overall evaluation of control alternatives. Criteria for evaluating the boll weevil eradication trial include:

1. Approximately 99 percent reduction in potential overwintering boll weevil populations in the evaluation area by the fall of 1977, the first year of operations.
2. A further reduction of 75 percent of the remaining 1 percent of the overwintering population in the spring of 1978 with saturation trapping and a modified trap crop scheme.
3. Population levels reduced to 3 or less weevils per acre by the time fruiting begins in the second year.
4. Approximately 10 percent or less of the evaluation acreage found infested during the second year of the program.

5. No evidence of boll weevils infestations in the evaluation area after July 15, 1979, the third year of program operations.

Environmental Evaluation

Primary and secondary program effects of both the eradication trial program and the optimum pest management demonstration programs on the environment will be evaluated. The environment in this case, includes, but is not limited to air, soil, water, and wildlife. The programs will be assessed for cumulative effects on the environment, if any.

Specific items to be evaluated include:

1. Total use of insecticides on cotton and other crops.
2. Impact on other cotton pests.
3. Impact on other crops.
4. Other environmental considerations--health of farm operators and labor; wildlife, and so forth.

Overall Evaluation

The biologic, environmental and economic evaluations will be used to examine the trade-offs among alternative boll weevil control programs and to determine the feasibility for beltwide implementation. Plans are being developed for the overall evaluation.

Independent Evaluation

OMB has suggested that the department consider a private research firm to conduct an independent evaluation of the boll weevil studies. Plans are being developed.

Concluding Comments

1. Important characteristics of the two boll weevil trials are:
    a. The optimum pest management trial will rely on voluntary participation of growers in a community wide program of integrated use of chemical, biological, and cultural control practices. Thus, information delivery and education of growers are important to assure success. If implemented, the cost/benefit ratio should be similar from year to year.
    b. The regulatory function is critical for the eradication trial 100 percent participation by farmers, to permit program personnel, to perform necessary chemical, biological, and cultural control practices. Costs versus benefits will be high during the eradication phase. After eradication, maintenance control costs should be minimal and benefits high.
2. A detailed but realistic plan is essential to insure an effective and valid evaluation of boll weevil control alternatives. As yet, preliminary plans have not considered institutional and social implications of the alternatives.
3. The most difficult part of the evaluation will be the extrapolation of the results from the large area eradication and optimum pest management trials to beltwide implications and the specification of current boll weevil control practices for comparison with eradication and pest management.
4. Communications and coordination of all activities, decisions, and so forth will require a major effort by operational as well as evaluative personnel.

RIVER BASIN PLANNING--A CASE STUDY OF INSTITUTIONALIZED TECHNOLOGY ASSESSMENT

by
Howard R. Thomas
Economic Research Service

River basin planning involves provision of information to decisionmakers about alternative uses of natural resources for which market structures are inadequate. Essentially, the purpose of river basin planning is to evaluate uses of the water and related lands of a basin, and to formulate plans for making the best use of these resources. There exist markets for some related lands; however, a significant portion of these lands are currently in public ownership. There exists no formal method of marketing water for irrigation without the land to which it is legally attached. Therefore, decisions concerning the allocation of limited natural resources must be made in the political arena, and must be based upon evaluation or assessment of alternative courses of action. Alternative resource allocations fit broadly within the scope of technology adaptation, and can be evaluated in terms of the same broad spectrum of effects; that is, economic, social, environmental, and so forth.

Institutions are often established to accomplish goals of society. The "national planning program stems from recommendations made in 1961 by the Senate Select Committee on National Water Resources, and further defined by Senate Document 97, 87th Congress, 2nd session." 1/ Senate Document 97 represented an effort to establish uniform guidelines for evaluation of water resource plans. Currently, the national planning effort is coordinated through the Water Resources Council (WRC). As part of their efforts to improve the comparability of resource plan evaluations, the WRC prepared Principles and Standards for Planning. 2/ This set of Principles and Standards is the current institution designed to accomplish the overall assessment of alternative resource development strategies.

The planning process involves two assessments. The first involves identification of significant problems in the basin, and the second is to determine the impacts of solutions (alternative proposals) to those problems. Resource planning under WRC auspices involves two overall objectives. These objectives provide the starting point from which identification of specific study objectives can be formulated. These objectives are: 3/

- "To enhance national economic development by increasing the value of the Nation's output of goods and services and improving national economic efficiency, and
- To enhance the quality of the environment by the management, conservation, preservation, creation, restoration, or improvement of certain natural and cultural resources and ecological systems."

The Principles and Standards continue: "For each alternative plan there will be a complete display or accounting of relevant beneficial and adverse effects on these two objectives." 4/

1/ Columbia North-Pacific Region Comprehensive Framework Study of Water and Related Lands, Appendix I, History of Study, p. 3, December 1971.

2/ Water Resources Council. Water and Related Land Resources Establishment of Principles and Standards for Planning. Federal Register, September 10, 1973, Vol. 38, No. 174.

3/ *Ibid*.

4/ *Ibid*. p. 6.

Step 1 in figure 1 calls for a determination of the objectives of the study. These objectives will be distinct statements of problems arising from either degradation of economic and environmental resources, or an assessment of basin resource capability to satisfy projected demands for food, fiber, and recreation.

FLOW CHART OF STEPS TO IDENTIFY OBJECTIVES
AND CORRESPONDING EVALUATIONS AND INVENTORIES

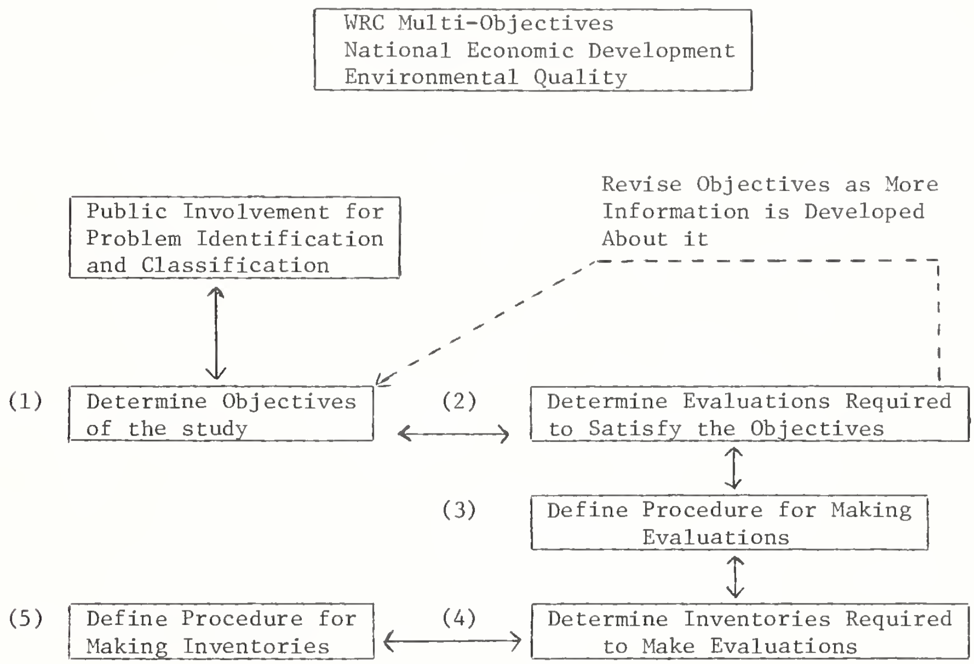


Figure 1

Problem solving is the central theme of the river basin planning program, involving assessment of benefits and costs associated with alternative solutions to problems.

Public participation is a vital ingredient in the problem identification process. The public can be differentiated into three relatively distinct segments: national, regional, and local. Within each of these levels of interest are many special interest groups with a particular interest in the results of the planning process. Each of these publics must be identified and their input solicited throughout the study.

Once problems have been identified, prioritized, and incorporated into a study objective, the issue becomes one of what can be done to satisfy the objective within the programs and authorities currently available. The planning staff is not limited in its search for solutions by current policy and institutional constraints; however, current policies, programs, and authorities must be considered as potential solutions.

The output of the study will include a list of actions which constitute alternative solutions to problems identified in the objectives. Definition of the

evaluations required for making decisions is the next step (see figure 1) toward identification of work elements required to insure a full assessment of the problem at hand. The full range of possible impacts needs to be evaluated; therefore, as many disciplines as possible should be represented in this activity.

The essential element in this process is flexibility. As the successive steps are accomplished, the study team (panel of experts) must be willing to revise previous conclusions to accommodate new information.

By following the procedure illustrated in figure 1, it is possible to identify those areas of importance that require additional information before the assessment can be completed. Gathering this information and following impacts through the accounting system will, theoretically, result in an exposition of all significant impacts of each alternative solution to the problems of the basin.

In order to do an adequate job of this, the publics of the basin should be involved in assessing the adequacy of the alternatives. Public involvement is an important element in the process of evaluating alternatives for utilization of natural resources. Public information is only the first step in obtaining adequate public involvement. The various publics must have a chance to provide feedback to the study team. Therefore, public involvement requires a set of formal and informal encounters to provide adequate opportunity for idea exchange. Public involvement is an expensive process, but well worth the effort if properly conducted.

Information collected is analyzed and interpreted by the study team. Interpretations are intended to be as objective as possible; however, the experience and abilities of the study team will be reflected in the final result of the study. Therefore, it is critical to obtain the best-qualified people to serve on the study team. They should represent those disciplines relevant to a thorough assessment of the impacts of plan alternatives.

A Type IV study normally involves assessment of several alternative plans designed to alleviate problems in a study area. 5/ These problems may range from insufficient upland bird habitat to flood protection. The brevity of this paper will not allow a full exposition of a complete impact analysis for the Type IV study. We have chosen, for illustrative purposes, an analysis of irrigation efficiency on a typical irrigation system in the Upper Snake River Basin.

The case study discussion is intended to display the planning process as it relates to a specific study item. The contribution of this paper is the exposition of study methodology rather than determination of plan effects. Conclusions are tentative, and will probably change as the study is completed.

The case study that follows is concerned with potential impacts of enhancing irrigation efficiency in the Upper Snake River Basin.

A Case Study

USDA and the State of Idaho, cooperating in a Type IV study 6/ of the Snake River Basin in Idaho and Wyoming, established a cooperative research unit to assess the potential for improving the efficiency of the distribution and use of irrigation water in the study area.

Through exchanges with irrigation companies in an effort to collect information on irrigation efficiencies, an irrigation system was selected for detailed analysis. A linear programming model was developed to determine the least cost method of rehabilitating the system to improve its efficiency.

The system chosen for analysis is located in relatively flat topography, and is typical of many irrigation systems in the area. The initial studies related to technical feasibility of efforts to improve the efficiency of the system and selection

5/ Type IV studies are cooperative between State water resource agencies and the Department of Agriculture. They are carried out under authority of Section 6 of Public Law 83-566.

6/ Cooperative River Basin studies authorized by P.L. 83-566, Section 6.

of the most cost-effective method of accomplishing that improvement. A general conclusion was that on-farm irrigation application systems offer more opportunity for improving irrigation efficiency than distribution systems.

Once the question of technical feasibility had been adequately addressed, the efforts of the cooperative unit were directed toward identifying potential impacts of alternative means of effectuating the desired change in irrigation efficiency.

The impacts of rehabilitating a system (adapting improved irrigation applications technology) include economic, social, institutional, and environmental effects. Direct and contingent effects must be determined and displayed to provide public decisionmakers with all of the relevant information they require to make rational decisions.

Economic Impacts

In many cases, cost per unit of production will decline due to changes in irrigation application methods. This is due to factors affecting both long and short term productivity. Factors affecting short-run productivity include erosion and sediment damages, improved timing of water application, better distribution, and retention of applied nutrients, etc. Long term factors would include erosion, 7/ retention of nutrients, increased irrigable acreage due to reorganization of onfarm distribution systems, and related improvements. Many studies have produced estimates of the economic benefit of these factors. More complete estimates of benefits would include values in alternative uses for the water. Alternative uses in the downstream areas will determine the value of actions designed to improve overall irrigation efficiency. Benefits can accrue to irrigation in the absence of declining per-unit costs. If production is increased and per-unit costs remain the same, the net income of the farmer-irrigator will be increased. It is important, then, to consider not only cost of production but also the net income situation when determining benefits. This is especially important when comparing public versus private effects of adopting new technology.

Two simple cases will illustrate the importance of public versus private benefit derived from changes in technology that result in different situations relative to productivity and/or cost per unit of product. Benefits may accrue on site and/or downstream when water-saving technology is adopted. The cases considered here assume that public and private benefits are equal in downstream areas. Consider:

Case 1:

a. Per-unit cost of production declines;
b. Total production per acre remains constant;
c. No increase in acreage results from the change in technology.

Cost per unit declines from $0.10 to $0.09. Private benefit will be $1 per acre, assuming 100 units total product and no change in product price. Since production has not increased, there is no public benefit.

Case 2:

a. Per-unit cost of production remains constant;
b. Total production per acre increases;
c. No increase in harvestable acreage (on site).

Cost per unit = $0.10; product price = $0.12; total production increases from 50 to 100 units. Private benefit = 50 x $0.02 = $1 per acre. Public benefit = 50 x $0.12 = $6 per acre. These annual values must be discounted over the life of the technological improvement to determine the actual benefit.

These two cases obviously do not exhaust the potential variations that could occur. Water-management ability of the individual farmers in a study area will influence how much public and/or private benefit will accrue in that area.

7/ Long term erosion effects are related to loss of surface soil to the extent yields are affected. This effect is differentiated from short term erosion which reduces harvestable acreage in a crop year.

New irrigation development, power production, instream flows for aesthetic purposes, and supplemental irrigation water for water-short areas are a few of the alternatives that could be considered for saved water. However, there needs to be an institutional framework established to both provide incentives for saving water and distributing the saved water among competing uses.

Benefits would need to be determined by experts in the field. Since there is an interaction between the aquifer and the stream, it is very difficult to quantify the actual amount of water saved. In effect, much of the water isn't saved, but merely transferred downstream, either through the aquifer or in the stream, depending upon whether it is diverted or not. This interaction is accounted for in a computer model of the Upper Snake Basin. It can be shown, using this model, that the water diverted is essentially all returned to usable sources; however, the time delay associated with diverting through the aquifer is not precise. In water-short years there may be some economic benefit associated with reduced diversions that will average out in the long run.

The conclusion, then, for economic consideration, is that little if any economic benefit can be attached to reductions in diversions other than the onfarm benefits from increasing yields and system benefits associated with smaller flow rates through the channels.

Total economic impacts would be estimated in two steps: (1) Primary impacts would be determined for each irrigation system, given the achievement of an acceptable level of efficiency. (2) Primary impact estimates would be input to a state-wide Input-Output (I-O) model to determine economy-wide impacts.

Environmental Effects

Assessing environmental effects of changing irrigation technology covers a wide range of potential impacts. Potential impacts include, but are not limited to, the following:

- Upland bird habitat.
- Small game habitat.
- Instream flows for fish habitat and dilution of various pollutants.
- Reduction of nonpoint pollution from irrigated agricultural lands.
- Increased demand for energy, related to increased pumping requirements results in new hydro- or thermal-generating facilities which often degrade the environment.
- Changes in scenic values associated with changing onfarm systems.
- Vector control.

The effect on these and other environmental factors must be described and evaluated on a case-by-case basis. In the past this phase of our analyses has been neglected because of the emphasis on favorable benefit-cost ratios. As our population grows, and land and water available for agricultural use become scarce, it becomes increasingly important to consider the full range of environmental effects.

POTENTIAL ASSESSMENT OF CHANGING TECHNOLOGIES IN FOOD FORMS

by
Larry Traub
Economic Research Service

Over the past 25 years consumers have been inundated with new or modified "highly processed and refined foods." In 1973 alone, food companies introduced 7,200 new products or variations for the retail market, according to A.C. Nielson Co. (2). In addition to the retail market, these companies have introduced sundry new products for the industrial and institutional market. Most of these products are minor variations of existing food products, while some products are a result of a new food form. But whether a "me too" product or a new product, they are derived from a new or modified existing bundles of technologies: flavoring, texturing, preserving, coloring, packaging, and so forth. Almost all of these products are highly processed. 1/

The food industry's reasons for introducing new products, other than profit, are to provide consumers with food products having superior convenience, quality, taste, freshness, availability, and variety over the current food products offered. The industry also argues that highly processed food products are a response to changes in consumer demand brought about by rising income, increasing opportunity cost of the homemaker's time, a growing negative attitude toward food preparation, and changing lifestyles. Futhermore, industry spokesmen point out that this activity does contribute to employment and economic growth.

Consumers reactions have been mixed to the marketing of new bundles of technologies via food products. For instance, the yearly sales value of frozen plate dinners, better known as TV dinners, increased 75 percent from 1965 to 1974, to over the $½-billion level. But TV dinners decreased by 18 percent from 1971 to 1974. Sales of frozen snacks, (hors d' oeuvres, eggrolls, snack logs not pizza) increased by 85 percent from 1971 to 1973, but decreased by one-third from 1973 to 1974 (7). Per capita consumption of frozen vegetables, on a fresh weight basis, rose from 17.4 pounds in 1965 to 20.9 pounds in 1974--an increase of 20 percent (10). But, the sales of prepared vegetables (those garnished with sauces and cream or combined with another vegetable or food) decreased 7 percent from 1972 to 1973 (8) However, the per capita consumption of one frozen processed food, French fried potatoes, increased 131 percent during 1965-75. These buying behavior changes can be attributed partly to consumer reactions to arguments that processed foods are a major source of high food prices and inflation, a major user of energy and nonrenewable resources, a major contributor to today's lifestyle, and a major source of declining health and food product safety.

But market variability in processed foods as exhibited during the sixties and seventies enhances "market failure" cost (costs that become embedded in the structure of the marketing system). With these costs remaining high, firms are reacting by curtailing new production, marketing, and capital costs, and firms are establishing stiffer performance standards on new products before introducing them to the marketplace (1).

1/ In this paper, highly processed foods will be defined as any foods which have been altered so that significant preparation time, culinary skills, or energy inputs have been transferred from the homemaker's kitchen to the food processor and distributor. Most of these foods can be classified as convenience foods.

Research Thrusts

For many years, ERS has conducted research on the impact of new food forms or products on food marketing costs and margins. When ERS reorganized in the early seventies, a project on market potentials for U.S. farm products in domestic and foreign markets project was initiated. One major research thrust was:

1. To determine market acceptance and penetration of new or modified highly processed foods;
2. to determine their impact on marketing and food costs; and
3. to determine factors associated with product successes or failures to aid the research and development process in selective application of technological advances at least costs.

A convenience food study was conducted under these objectives. Preliminary results indicate that only 36 percent of the 162 processed foods studied had a comparative cost advantage over their nonprocessed food forms. And over 80 percent of the convenience foods introduced since 1960 were more expensive than the cost of ingredients needed to prepare them at home. However, 16 single-ingredient vegetable convenience products in frozen and canned form were cheaper than their fresh or home-prepared counterpart. For example, frozen orange juice concentrate was the best orange juice buy. Soy protein added to ground beef at home. Most of the highly processed meat dishes were more expensive than those prepared from basic ingredients (9).

In our final report, the homemaker's time of preparation and energy cost will be taken into account. In addition to comparative cost of convenience foods, we will analize convenience foods, consumer opinions of convenience foods, sensory perceptions of selected convenience foods, and factors associated with successes and failures of convenience foods.

We now have broadened our horizon and are concerned with the secondary impacts on society as the food products made possible by changing technologies are integrated into our food system. Consideration is being given to the feasibility of expanding the technology assessment components of the research. The broader project thrust can be fulfilled by the addition of technological variables to the present study. As the research problem is being defined, technology variables having broad futuristic impacts will be included in the study.

Several previous papers and studies on technological assessment have revealed sectors in society that can be affected by technological development (3, 4, 11). One such area is energy utilization and conservation. In the near future, frozen highly processed foods could be packaged in retort pouches. This packaging alternative could reduce the quantity of processed foods sold in the frozen state, which means less energy would be consumed by the food system. The lower energy requirement then can be translated into less oil imported and into a better balance of payments. Also, nonrefrigerated trucks and railcars, which have a lower energy requirement than refrigerated trucks and railcars, would be in greater demand.

Also, a new food form could have an impact on the healthfulness of consumers. According to "Forbes" the average person already eats more than 5 pounds of chemical ingredients per year (5). Some of these chemicals are now being questioned as having possible undersirable side effects--they cause cancer and hyperkinetic behavior in children. The problem is the food processing industry possesses extensive knowledge in food chemistry for solving production and marketing problems, but does not have enough information about chemical ingredients to evaluate their impact on human and ecological systems. So, undersirable health side effects from new food forms need to be recognized and their social impact evaluated.

Increased consumption of highly processed foods has been accused of causing disunity in the American family. The argument goes that the convenience of time and ease in preparation of highly processed foods has allowed individual members of the family to eat their meals separately rather than eating meals as a family unit: a condition that reduces communication among family members and, hence, increases family tensions.

Several million workers are employed in food processing. The advent of a new food form could cause some structural and locational unemployment. Alternatively, with the

mobility of our society's labor, a net increase in employment opportunities could emerge with successful introduction of a new food form, an event that could increase our gross national product.

Agricultural production can be adjusted with changes in the mix of foods consumed. For example, the proportion of processed vegetable production to total vegetable production has increased by 9 percent from 1965 to 1974. During the same time period, citrus fruit production increased by 67 percent as a result of the rising consumption of frozen orange juice concentrate. The demand for frozen French fried potatoes and dehydrated potatoes has increased. The proportion of processed potato production to total potato production increased by 11 percent from 1965 to 1974 (10). So, as the demand for a food shifts, what is being produced on the farm also shifts. But, is one farmer improving his "stake" at the expense of another farmer? Or is the lot of the whole agricultural community improving?

Another concern is the impact of new food forms on the market structure of the food system. Even though universities and government (mainly USDA) have played a substantial role in technological change in food forms over the past decade, much of this change has precipitated from research and development facilities of large food processing firms. Many market structure theorists feel that firms have used technological change in food forms to differentiate their products, to increase their market power, to monopolize food prices, and to enhance their firm's profit position. Further, Padberg feels that greater "market power" allows firms to experiment on new foods, which may not be consistent with long-run healthfulness, and to create images of these products which may not be compatible with public interest (6).

What has been attempted so far is to show that changing technologies in food forms could have an impact on many segments of society. But, to realize that any area in society can be impacted in the future with new product development means that the problem statements needs to be expressed more thoroughly starting with no real or implied boundaries. This approach will reveal the complexity of the problem and of the analysis. Narrower problems may require only modification of traditional analysis. The more complex problems will require a more complete framework. One such approach is conceptualized in figure 1 and it shows cause/effect relationships between the new food form and society. 2/

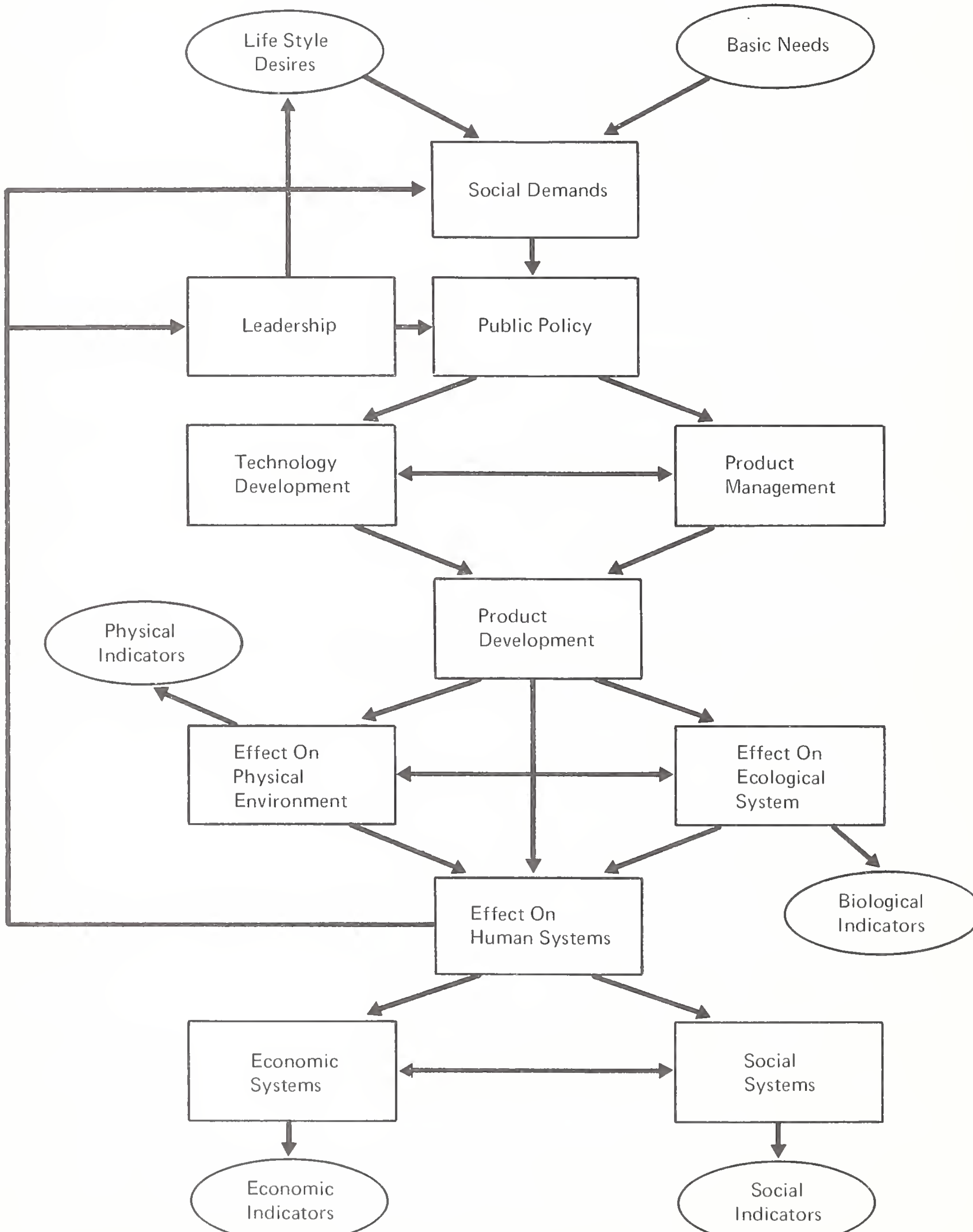
Conclusions

In a "free-market economy," the individual consumer ultimately chooses which highly processed food products remain on the market. That is, consumer acceptance of a product is a necessary requirement if the product is to have any impact (negative or positive) on society. To many people, any collective consumer participation in the decisionmaking process of assessing market introduction is just an axiom for social control of technology. But many areas in society can be impacted with new technologies. So, public participation in the implementation process of new technologies of food forms may be necessary if more meaningful solutions are to emerge.

ERS' participation in the implementation process of new technologies of food forms can be handled by adding technology and impact variables to the current study. Or, if the technological change in food forms seems to have the capability of having a broad and significant impact on society, a technology assessment candidate study could be developed and implemented.

2/ This conceptualization of technological assessment for product development is a modification of the TA framework developed by Leo W. Weisbecker, Stanford Research Institute.

Figure 1
Conceptual Framework for Technology Assessment of Product Development



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TOWARDS TECHNOLOGY ASSESSMENT OF MARSHLAND MANAGEMENT

by
Jeff V. Conopask
Economic Research Service

Land use management has taken on new meaning because of the heightened interest in environmental problems. This "rediscovery" of man's ambient setting is of particular concern when dealing with unique landforms such as marshland, specifically those affected by the oceans. 1/ These landforms, in their natural state, offer technological opportunities to a number of manmade activities.

Given the continually increasing demand (development and environmental) for coastal zone sites, inevitable conflicts over resource use will arise. Since the private market is not functioning very well with regard to the allocation of services provided by the marshlands, another mechanism must be found to evaluate the benefits and costs of alternative marshland uses.

One such possible mechanism is technology assessment, whereby the values of preserved marshlands can be compared, where appropriate, to manmade surrogates. The perspective of viewing the natural services vs. the manmade surrogates is of fairly recent vintage. 2/

Technology assessment is akin to socioeconomic planning. 3/ The kinship is oriented about the impact studies (proactive and reactive) which physical, life, and social science researchers have produced. Management is a judicious use of means to accomplish an end, that end being the socially best use of an ecological and economic resource.

The broad question for consideration here is: what is the best way to produce certain services given a location site demand? For example, if a hotel is put on the marshland site, then flood control structures may have to be built as well as a waste treatment facility. The first task will be to discuss future problems of marshland management, with a focus on a new technology, marshland synthesis. Then, two studies, neither of which were designed as technology assessments, will be briefly critiqued. At best, these studies could be characterized as partial TA's.

Marshland Management Problems

Coastal zone and wetland-specific legislation have temporarily slowed the destruction of tidal marsh areas. This does not mute the need for impact analysis, but should be viewed as a gain in time to improve our understanding of the natural processes occurring in the marshes. The current slowing of marshland alteration may change with

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1/ Freshwater marshlands will not be covered in this paper, although technology assessment could conceivably be used to evaluate such alteration situations as rice/catfish farming in the Arkansas delta and wheat farming in the upper Midwest pothole country.

2/ The author is aware of only one study or project where this conceptual framework was initiated, although it was not known or considered as TA. This is the case of the Upper Charles River Flood Control Project where a recommendation was made that existing marshes be preserved because of the spongelike quality of their peat bottom in absorbing and controlling the subsequent release of storm water and runoff. A system of dams and levees was not required, thus, saving other marshland qualities. See (19).

3/ Black has a concise discussion of planning studies kinship to technology assessment. See (2).

the political winds or increased demand for expanded public access (industrial or recreation) to the intertidal areas.

Marshland synthesis may change this situation and revitalize man's perennial optimism in out-engineering nature. A more accurate assessment of marshland alteration will be required because of the potential replacement possibilities. Statements such as the following from an article in a professional engineering society journal must be carefully weighed:

> "...it has only recently occurred to marsh ecologists that destroyed marshes may be regenerated or replanted and that new marshes can be created (7)."

Essentially an offshoot of beach and dune stabilization efforts, marshland synthesis offers both the promise of partially replacing destroyed marsh, plus augmenting existing marsh and offering a replacement in another location for existing marsh. While this may seem fair on the surface, marsh geomorphology suggests that (a) marshland developed where it did for specific geological reasons, and (b) extensive, well-developed (vertically and horizontally) marsh areas may take thousands of years to develop (20). Thus an apparent quid pro quo site trade may only be fair in terms of hundreds or thousands of years.

Some attributes of tidal marsh can be reproduced rather quickly, as shown by the dredge spoil stabilization efforts in Alabama, Georgia, and North Carolina (7, 19, 23). Wildlife food supply and habitat functions of the surrounding estuarine area have been expanded. As the spartina grasses expand through their rhizomes and seed, the soil stabilization of the wetland bottom will become more geologically efficient. Also, the sediment trap characteristics can be expected to become more efficient. Only through time, however, will the flood control service of mature tidal marsh peat beds (underlying the marsh bottom) become effective. Only until extensive thick fields of the spartina grasses develop after many growing seasons, will the wave buffering action of the marshes be effective. Since newly created marsh does not have the thick layers of sediment/peat, it will be some time before they act as buffering agents for any large additions of phosphate to the estuarine system (12). Other questions also remain as to the other waste-assimilative capacities of these new marshes.

Although new advances can be expected, only one continuous ongoing program has successfully reestablished marsh characteristics in a rehabilitated landform on relatively small tracts (.5 to 5 acres) (8). Extensive marshland rehabilitation may be a viable technology in the future for augmenting or reproducing certain characteristics of natural marshes, but because of the time dependent growth of those systems, certain characteristics, if destroyed, are irrecoverable. Careful policy analysis on a regional ecology basis will be required if the marsh synthesis technology is to be considered a viable policy option.

According to Bender, the first comprehensive compilation of the available information on systems of salt and tidal marshes was in Chapman's 1960 monograph (1). Most other estuarine research including tidal marsh has been devoted to the flora and fauna of unmodified eco-systems. The research results suggest that significant environmental values are available from the marsh in their natural state, including the mispriced products of the commercial fisheries, recreational fisheries, fowling and trapping, as well as the unpriced services of erosion, flood and sedimentation control, waste-assimilative capacity, and fresh water aquifer protection (13, 17, 22). 4/ The services of wildlife production are mainly obtained through the natural wetlands. The unpriced services can be obtained by human surrogates (that is dredging, levees, waste treatment plants, and so forth) which either augment nature or substitute for it.

4/ A recent paper by Walker has taken a devil's advocate role in challenging some of these environmental services. See (20).

All of these economic values have eluded measurement because of their open access nature, option supply potential, and alteration irreversibility characteristics. 5/ However, a number of efforts have attempted to place estimates on these services (9, 22). All of these efforts can be considered as attempting to account for some of the heretofore uncounted (external or secondary) effects of marshland alteration.

Critique of Two Studies

Two studies will be briefly reviewed. The first is a limited regional land use planning effort for Virginia's Eastern Shore. The second is a site specific analysis of alternative highway construction approaches through a tidal marsh in Louisiana.

The Virginia Study

The Virginia study explored the pattern of marshland development and preservation resulting from an ecologic-economic valuation. 6/ A linear programming model was utilized for the investigation because of its ability to consider various resource activities. The objective was to maximize gross regional social product under specified constraints on environmentally disturbing land use activities. The constraints of the model included the finite availability of three grades of marsh, segregated into bayside and seaside locations. The inventory was constructed by analyzing geologic survey maps. Applying bio-geological criteria to the acreage in question allowed the separation into high, medium, and low ecologically valued marsh. The criteria identified those marshland areas more susceptible to frequent flushing by tidal action, hence more valuable in an ecological life support system sense. 7/

The preservation services included in the analyses were first linearly estimated individually for an average grade of wetland and then combined into what represented a ecologic-economic return to the medium priority marsh. For high value marsh, 125 percent of the return to the medium priority marsh was used. Similarly, 50 percent of the value of medium marsh was used in calculating returns to low priority marsh. A development tax was incorporated to penalize alterations activity considered ecologically damaging.

The preservation services were aggregated after initial experimentation with individual service coefficients revealed severe modeling problems. The effort to maintain a social accounting of each service resulted in untenable solutions such as allocating more wetlands than existed. 8/

Out of some 98,000 acres of tidal marsh, 10,040 acres of low ecologic priority marsh were allocated to a development activity, marinas. This corresponds to all of the low ecological value marsh on both the bay and seaside of the Virginian Eastern Shore. The $512-per-acre tax prevented any lagoon housing from entering the solution. However, not all of the marina land need be separate from any permanent or seasonal housing. Although not built into the model, some of the marina land could be interpreted as servicing "cluster housing of multiple units" located near the water on dry land. Thus, the demand unrestricted level of marina land may be realistic when viewed as both separate for traditional boating pursuits and as servicing cluster recreational housing.

5/ Open access is a more precise legal term than common property; option supply refers to uncertainty in the future production of an environmental service; and irreversibility reflects nontrivial inflexibility in polyperiod production. See (4) for a broader discussion.

6/ This small study was part of a larger research project on coastal zone management. See (5).

7/ The bio-geological criteria are extensively developed in (5), and are based on (14, 22).

8/ Similar problems on a similar project were expressed in a letter dated April 12, 1973, to the author by Dr. James Stepp of Clemson University.

With the high-and medium-valued marsh kept in a preserved state, the gross regional social product rėmains very near its base solution level, even though the complexion is different. Table I presents this new complexion.

Using linear programming to maximize regional production subject to environmental constraints is not a new idea--it has been done by a number of different groups in the recent past. 9/ The Virginia study considered land as productive in its natural state without the application of labor and capital. This is a significant departure from the traditional idea that only through the application of labor and capital, would land become productive.

Earlier programming studies considered only a single activity occurring on a specific site. This does not preclude the consideration of joint products for a specific process where the definite production relationships are known (11). One could even include the amount of residuals produced by such a process. However, the concept is not easily transferred into an ecologic model because of the simultaneous production of a package of inseparable preservation services, some of which are not fully utilized as an economic resource at a particular time and all of which are mispriced in the private market. While the mispricing creates difficult enough problems, the estimation of the demand requirements or resource utilization are not very well defined.

The Viriginia study was a crude initial attempt at assessing the regional impact of various wetland uses. The methodology of economic valuing of qualitatively different ecologic resources needs additional progress from the physical and life sciences to make this direct approach workable, although it shows promise. The use of linear programming in this context does not appear appropriate because of the theoretical and mechanical problems cited above.

The Louisiana Study

The Louisiana research used an indirect method for marsh valuation, and proved slightly more promising, albeit there were problems with it also. That study attempted to calculate "values for individual components of the system" of total life support value based on the primary productivity of the marsh (16). That value was then used in an analysis of highway construction through coastal marshes. The authors state "that except for cases of very shallow spoil removal, bridging is cheaper and ecologically preferable to filled roadway construction" (16).

Using earlier work, the authors developed their analysis on the estimated foregone values of the marsh using a comparative energy-economic indicator (9). The key to the life support system valuation was a ratio of gross national product and national energy consumption. This ratio, an average for all U.S. production, approximates the amount of energy required per dollar of U.S. output. By applying the ratio (one dollar per 10^4 kilocalories) to an estimate of gross primary production (photosynthetic organic matter) for marshland, the authors arrive at a "figure for the total of evaluated uses, incommensurables and intangibles". Their estimate of total life support system value was approximately equal to a selective, non-all inclusive sum of quantified noncompeting values.

As expressed in table 2, unless the spoil removal is a minimal problem, each of the bridge construction alternatives is superior to convential roadway fill construction. The difference is accounted for by the marsh loss minimization. Although the bridge building costs are up to four times as much as the cost of filled roadway, the valuation of the potential marshland loss makes an argument for the former.

Although Pope and Gossalink have shown creativity in their ingenious tying of energy to a monetary valuation, certain problems remain. Their use of GNP represents a value-added approach for all inputs. A more accurate representation would have been the value of energy production alone. Hence, their usage has an upward bias. On the

9/ Two noted examples, although fraught with their own problems, are Heady inspired research and that of Pimentel and Shoemaker. See (10) and (15).

Table 1--Complexion of gross regional social product of Virginian Eastern Shore wetland services 1/

Wetland ecological location and grade	Preservation service (components) Fisheries	Water-based	Fowling	Erosion control	Marina	Lagoon housing	Total
				Dollars			
Seaside							
High	42,814,470	566,384	141,604	--	--	--	43,522,458
Medium	8,176,652	134,691	33,673	2,257,402	--	--	10,602,418
Low	--	--	--	--	5,974,151	--	5,974,151
Bayside							
High	9,133,586	120,833	37,823	1,937,533	--	--	11,229,775
Medium	2,304,490	151,054	13,979	1,217,189	--	--	3,691,512
Low	--	--	--	--	1,847,009	--	1,847,009
Total	62,428,998	972,962	232,079	5,412,124	7,821,160	--	76,867,323

1/Calculated by multiplying the objective function activity coefficient times the number of acres used for that service.

Source: (5).

Table 2--Comparison of present cost to society of construction of a filled roadbed or bridge across 100 feet of marshland, evaluated over 60-year period at 5-percent interest rate

Highway alternatives	Present discounted cost 1/
	Dollars
Highway cost, 2.5 ft. spoil removed	131,727
Highway cost, 8.0 ft spoil removed	329,430
Bridge cost, concrete poured in place	140,411
Bridge cost, prestressed sections	122,651

1/Marshland valued at $4,150 annual benefits per acre.

Source: (9).

other hand, one can draw strong arguments that the current price of energy is way below its social price and that we are living off of a capital item, not a renewable resource (which, incidently, a preserved marsh is). Thus, their valuation has a downward bias. Curiously enough, however, this reviewer suspects that, on balance, the actual social values are much higher than even they dared estimate because of the relationship with energy.

Although Pope and Gossalink's work provides a comparative picture of some of the natural services value, certain questions still exist regarding their method. These questions pertain to the appropriateness of the energy comparison, the completeness of service coverage using the total life support system approach, the site variance in ecological value, and the future uncertainty expressed in the option supply concept. 10/

In conclusion, Pope and Gossalink do demonstrate that from a social efficiency perspective, it is incumbent on highway planners to consider certain nonmarket costs. They did ignore equity and social impact issues, per the initial design of their research. As with the Virginia study, the design was towards examining techniques for direct preservation service impacts, and not towards socioeconomic linkages with other sectors.

Conclusions

It is obvious that much research remains to be done in order to implement assessment techniques for achieving longrun economic and ecologic efficiency of the marshland resource. A noted marine scientist, Eugene Cronin, sums up the issue with the following:

> "The benefits which may be derived from proper management of coastal areas are great enough to merit the costs" (6).

10/Additional secondary impacts need to be considered, such as the changed hydraulic patterns of other marshland acreage because of filled roadway construction. The study was designed only for primary acreage impacts.

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TECHNOLOGY ASSESSMENT--ARS RESEARCH DEVELOPMENTS

by
Dwight L. Miller
Agricultural Research Service

Consideration will be given in this paper to some of the delegations, research activities, developments, and evaluation of performance of the large ARS-USDA Regional Research Centers and their relations to technology assessments. Actual cases at the Northern Center in Peoria, Illinois, will be used to illustrate typical experiences, in accordance with our missions and delegations to carry out agricultural research.

Historical Background

The Agricultural Adjustment Act of 1938 authorized the Department of Agriculture "to establish, equip, and maintain four regional research laboratories, one in each major farm-producing area, to conduct researches into and to develop new scientific, chemical, and technical uses and new and extended markets and outlets for farm commodities and products and byproducts thereof. Such research and development shall be devoted primarily to such commodities in which there are regular or seasonal surpluses, and their products and byproducts."

These large laboratories (now called Regional Research Centers) are located in Peoria, Illinois; New Orleans, Louisiana; Wyndmoor, Pennsylvania; and Albany, California. They are all approximately the same size with staffs on the order of 400 of whom about 200 are classified as scientists. The many major achievements of the Centers have been documented by over 200 selected examples. At least 150 of these are designated as "commercialized."

Programs of the Centers are organized on a commodity basis. They include practically the entire spectrum of crops that are of importance to American agricultural interests, although principal emphasis is placed on the largest U.S. crops. Many special research programs have been undertaken because of their contribution to the nation's general welfare.

The major research program areas are cereal and forage crops; cotton, wool, and mohair; oilseeds; animal products (including dairy products, meat, animal fats, hides and leather, and poultry and eggs); fruits and vegetables; and new and special plants.

Complete technology assessments (as now considered) have not in the past been made on the program areas or individual projects on which research has been conducted. Yet, the achievements of the Centers have been outstandingly successful. We can thus only speculate on what the achievements might have been if assessment study results had also been available. Perhaps we will find out in some future research programs.

These research programs and activities, however, were not set up or conducted haphazardly without planning. They were carefully considered by administrators, involved scientists and many other qualified people. Thus, a degree of overall technology assessment was, in reality, made. However, many phases of projects were never considered as important in the past. For example, little attention was given to energy conservation, to waste disposal factors, to the effects on the environment, to the effects on the workers or on items with which the development might compete or replace, and to other social effects.

Research Developments

With the foregoing general information and background, my further discussions will be concerned with some activities at the Northern Regional Research Center. Some of our most important developments will serve as a basis for technology assessment considerations.

NRRC has had a highly diverse research program, primarily concerned with products from important crops in the 13 States of the North Central Region. These crops include all of the cereal grains, soybeans, flaxseed, new crops, and related byproducts and residues. One of our research groups is known as the Fermentation Laboratory. Since 1940, we have had a large culture collection. It is probably the world's largest industrial collection. It consists of over 49,000 selections of yeasts, mold, and bacteria--practically all of the nonpathogenic type.

The advancement of fermentation from an art to a science began in the latter part of the nineteenth century with the work of Pasteur. Since then, we have seen such miracles as the discovery of penicillin, streptomycin, and other antibiotics produced by fermentation. In fact, learning how to mass produce penicillin at NRRC in the forties opened the era of antibiotics and a whole new industry. Many of you would not be here today, except for those developments. You or your ancestors would not have survived.

In 1954, a representative of a major industrial producer of gums met with NRRC scientists concerning the water-soluble gum producing capability of our large culture collection of microorganisms. The discussions that took place are not completely documented. However, it was informally decided that a culture screening program would be made by our scientists and the company would evaluate the gums produced. The screening resulted in 26 promising yeasts, molds, and bacteria produced gums that warranted further study. Six of the most promising ones were then selected and researched in depth. The findings were, indeed, rewarding.

At an American Chemical Society Meeting in 1959, polysaccharide B-1459 was first officially announced by one of our scientists. It is a polymer produced by the plant pathogen bacteria *Xanthomonas campestris* NRRL B-1459. It was later given the generic name xanthan gum. The fermentation media is primarily based on glucose derived from starch which is obtained from corn and other cereal grains, and these are some of the major commodities on which our research is conducted.

There was immediate academic and industrial response to the announcement of this new gum. Hundreds of companies wrote for more information, and innumerable visitors came to Peoria for in-depth discussions. Six industrial companies requested listing as potential commercial producers. Industrial followup has never stopped even after all these years--in reality it is increasing. Application interest has been for both food and nonfood uses.

Xanthan gum was initially utilized commercially as an industrial gum for such purposes as an oil-well drilling mud additive and a water thickener where its impervious nature to temperature, pH and salts, plus the control of flow and viscosity, offered many advantages. It has been used in fire fighting fluids, in paints, in oven cleaners, in auto polishes, in metal cleaning jelly, and hundreds of other products. It is now expected to become a key agent for the tertiary recovery of petroleum, a market that essentially did not exist when the gum was discovered, and a use for which it then would have not been economical to even consider.

Xanthan gum was approved as a new United States food additive in 1969 and is now also approved for food uses in most foreign countries. It has become an accepted thickening, suspending, emulsifying, and stabilizing agent in the food industry. Xanthan gum has also facilitated the production of new products that were previously difficult or impossible to produce. All of us eat some xanthan gum almost every day.

It has been my fortune to have been involved in the evaluation and commercialization of xanthan gum since it was first announced. This included consultation on and inspection of the first commercial pilot installations which later grew to large

commercial plants. There is about \$50 million in plant construction now under way in the United States, and large installations have also been made in foreign countries. There is some indication that the world's future increased supply of food and industrial gums must come from fermentations of this type. Natural gums have been exploited to their limits and/or will become prohibitively expensive. Synthetic gums are primarily based on petroleum. The raw materials for these fermented gums are readily available from domestic renewable resources.

As stated earlier, fermented gums, and specifically xanthan gum, were developed without a specific overall technology assessment. A logical assumption at that time was that the raw materials would be available without disrupting existing industries. It was also assumed that the commercial equipment would be readily available as required. The bacteria was recognized as a plant pathogen but this property was considered to be of minor importance. Little consideration was given or believed necessary for many other phases of the development.

The assumptions did not always turn out as expected. Construction time schedules were seriously delayed because of unusually long equipment fabrication times. Production delays occurred because of solvent shortages. Production rates did not keep up with demands. Xanthan gum was on allocation for a long time.

Since 1958, an ERS economist has been stationed at our research center. Warren Trotter was the first one. He was followed by Clarence Moore. In 1974, Mr. Moore surveyed the market potential for xanthan gum in the petroleum industry. His findings were surprising. We had not realized such large volume usage might be possible. In reality, the petroleum industry was concerned about having adequate supplies to meet their requirements. More production capacity than now scheduled will be required if this total market develops. Several new production plants are now under consideration by industrial companies.

Many other NRRC developments are now in various stages of completion. For example, starch graft copolymers appear to be a family of promising new products. One of these in which polyacrylonitrile is the graft chemical has the property of absorbing and holding hundreds of times its weight of distilled water. This property was unexpected and unpredictable. Several thousand companies have already contacted us about it. Named "super slurper," it is not yet in commercial production, but is expected to be soon. Fifteen companies have already licensed our process patents yet the future of starch graft copolymers remains to be resolved. Interest has developed in practically every industrial field from agriculture (including handling of animal wastes) to cosmetics and diapers. We thus wonder--how can the value of such materials be determined before the research is done? Would a technology assessment have provided the answer? What types of assessments are now needed?

Certainly a major problem in research is how to obtain sufficient information to make correct assessments for action. In retrospect, we at NRRC have questioned several times whether current research activity evaluation procedures would have permitted some of our most successful research to have been conducted. The answers are not conclusive. We doubt that research on fermented gums, including xanthan gum, would have been adequately supported. How many future good developments have we dropped? We must not use evaluation procedures that would let such things happen. I thus pose the questions as to how advanced must the research knowledge and market information be for an overall technology assessment to be made? Then, how will the assessment be used?

In closing, I certainly favor initial overall technology assessment. Although such studies may not provide needed information on the many products and byproducts developed from the research as it progresses, they can provide major guidance for our research.

THE ROLE OF MODELS IN TECHNOLOGY ASSESSMENT 1/

by
J. M. Johnson
National Science Foundation

Different types of models play unique roles in acting out the three-part play necessary for a complete technology assessment. As an illustration this paper utilizes three policy models, and shows the breadth and scope of the roles they play in different stages of assessment. A model which can play the role of a social mixer is needed in the first scene of an assessment. In mid-phases, models utilized must be capable of playing the role of a builder who can separate component parts and put together a complex system in alternative ways based on different objectives. The final act of assessment requires models which can play the role of elegant designer to enhance human satisfaction with the new technology.

The planning process can be characterized by various modules or stages. Each stage requires the right tool for analysis. Modeling tools are emerging with such diversity of capability and form that a planner can now chose the right tool for the specific stage of assessment. Models play unique roles in the three phases of a technology assessment. They illuminate the structure of a complete problem statement, identify the tradeoffs involved in any decision, and determine the optimum allocation of resources.

I call these three roles of models the three T's--thinking, testing, and tasking--and operationalize these roles in table 1. Thinking models help to structure the components of a problem. Testing models identify the tradeoffs that result from specific alternatives, and tasking models help identify optimal resource allocation. Figure 1 on page 90 show the level of modeling effort required for each phase of assessment. In problem structuring, identifying the main components and their relationship is sufficient and can be accomplished in a week. In testing alternatives, more detailed models must be constructed over several months to trace through the social and economic consequences on our existing system of alternative technologies and policies. In the final phase, engineering and design parameters must be worked out with sufficient staff commitment to detail that real decisions can be made on the level of resources needed for feasible design and operation of a new technology. For the initial assessment stage of problem identification, a model capable of playing the role of a social mixer can replicate holistic thinking by facilitating specialists to contribute their piece of understanding to a complete picture of the problem. The purpose of this mixing role in problem identification is to have a more satisfying problem statement by including all of the multiple systems involved. Such a model is capable of combining minds and synthesizing their collective thought products for a grasp of the complexity of a problem.

1/ The opinions expressed are those of the author and do not necessarily reflect the views of the National Science Foundation.

Table 1.--Roles of Models

Human activity	Operational characteristics	Heuristic
Thinking	Problem structuring Logic synthesis	Philosophy
Testing	Tradeoff identification If this changes/then . . .	Simulation Judgement
Tasking	Resource allocation Problem solving	Optimizing

Structural analysis models can play this role of social mixer in identifying broad problem statements. These models seek to describe a situation in terms of a number of interacting variables in a dynamic mode. The analysis stems from observing changes in key variables as a result of interaction and interventions over time. Among a number of methods of structural analysis are Leonteif's (1965) input-output work, Forrester's (1961) systems dynamics method, Robert's (1972) work with signed directed graph theory, Teniere-Buchot's (1973) POPOLE model, Warfield's Interpretive Structural Modeling and Kane's (1972) work with a cross-impact simulation language, KSIM. Kane's work currently seems to provide a very appropriate technique for incorporating a structural analysis procedure into technology assessment. The method provides a way to involve experts from several disciplines, policymakers, and laymen in structuring a problem using both subjective and empirical data.

Thus, a modeling situation is not limited to a structure where only quantitative, precise variables can be considered. KSIM is also able to utilize subjective information on relationships among variables (in Kane's words, "geometic" information) to develop a dynamic model of a situation useful in initial assessment of relations.

The heart of the method utilizes a cross-impact structure to relate influences among variables which then is used to derive changes over time. These time traces of the dynamic interactions among the variables give a multidimensional evolution of the situation. A strength of the KSIM procedure consists in the rapidity with which it can be utilized. Typically, about six experts can significantly cover a major topic area in about 5 days. The output of the method shows growth and decline of the main system variables as time traces or future histories. Broad-scoped models such as KSIM, which can play the role of integrating disciplines, initially aid in a comprehensive picture of the problem and an identification of diverse policy choices for industry and government.

The social mixer model assures that various disciplinary perspectives are integrated in a consistent way. Participants in this phase of assessment who wish to utilize this type of model should have an understanding of their own discipline plus a broad perspective so that the model can facilitate their interface with other disciplines.

In midphases of assessment, models play a testing role, and trace through the social and economic consequences of alternative technologies and policies. A testing model can act as a scale, and weigh the tradeoffs involved in alternative policies. Models of this type are useful in getting a "hands on" appreciation of component parts, since they are able to handle refined data. Refined models are useful in the midphase of a technology assessment because they identify how to control some system or subsystem identified in the initial phase of the assessment. One example of a testing model is Shlomo Reutlinger's stochastic simulation of grain reserves. Reutlinger uses grain reserves for the equity issue in developing countries of maintaining food consumption during years of production shortfall. The analysis reveals that developing countries

could not afford the expense of storing sufficient grain to meet this objective. Rather a country would have to attempt a variety of means to maintain adequate consumption levels, such as trade, aid, and storage. The modest amounts of grain the government held in storage for bad years would be a cheaper source of food subsidies than purchasing grain in the commercial market. The simulation model used by Reutlinger differs from optimization models in that it can handle multiple objectives. Reutlinger does not calculate the average net benefits to everyone (producers, consumers, exporters, importers), but rather distinguishes who benefits and who pays among various interest groups under different storage levels.

The simulation model shows that the distributional effect of stocks are decisively influenced by trade and subsidy policies and sometimes change direction with increasing levels of storage activity. The model can evaluate policies such as subsidy, trade, and storage on the multivariate objectives considered relevant to decisionmakers. The following table (table 2) shows the benefits obtained on a scale from 1 to 8 for each interest group from alternative grain reserve systems. (One is desirable - Eight is undesirable).

The "desirability" rankings clearly show the tradeoffs of policy instruments on different objectives. For the objectives considered in this model and given the range of assumptions considered, the model was useful in indicating that trade would seem to come closest to meeting all the objectives. The objective of storage could be best pursued by first of all freeing trade and only then supplementing free-trade with storage.

Having identified the problem, and components and tradeoffs, the final phase of assessment would be aided by tasking models that can "hammer out the details" of feasible designs. Tasking, or system design models, attempt to make optimal use of materials and resources. For example, in their assessment of controlled environment agriculture (CEA), International Research and Technology (IR&T) is presently actively engaged in the task of system design. Their assessment has shown that the general design characteristics of CEA include control, artificial delivery of plant inputs, isolation of the CEA from the external environment and higher yields. A much more complex task is attempting conceptual design breakthrough possibilities among the particular design characteristics.

Design characteristics will be ruled by where the facility is being implemented. If water is scarce, but energy cheap, as in Kuwait where all water has to be desalinated, the design would be ruled by optimal use of available resources. On the other hand in Madison, Wisconsin, water may be cheaply drawn from the Great Lakes, so design would be fitted to their needs for a cheaper energy CEA.

Summary

The overall purpose of an assessment is to provide clearer choices. Models used throughout an assessment to understand relationships, judge alternatives, and specify feasible actions should ultimately facilitate better and clearer choices among emerging technologies. When the assessment phase is over, models can also facilitate the communication of results of the assessment. The role of the model here is a teacher, illuminating the alternatives with their attendant consequences and opening up the floor for discussion.

Some models appropriate to this role are scenario analyses and policy capturing. In the former the teacher shows snapshots of the future and highlights the social issues involved. In the latter she attempts to get a consensus by calculating the tradeoffs subgroups are willing to make among the dimensions of the problem. (Johnson, 1974).

Policy capturing is a structured normative planning exercise which reveals an individual's "policy." Policy is here defined as the implicit weightings assigned to various aspects of a problem situation. One is presented with an array of alternative scenarios and asked to rank and scale them according to personal preference. Each miniscenario contains several dimensions of a future lifestyle, and one is forced to make tradeoffs among preferred social, political, economic, and environmental conditions in the alternative futures.

THE ROLE OF MODELS IN THE PHASES OF ASSESSMENT

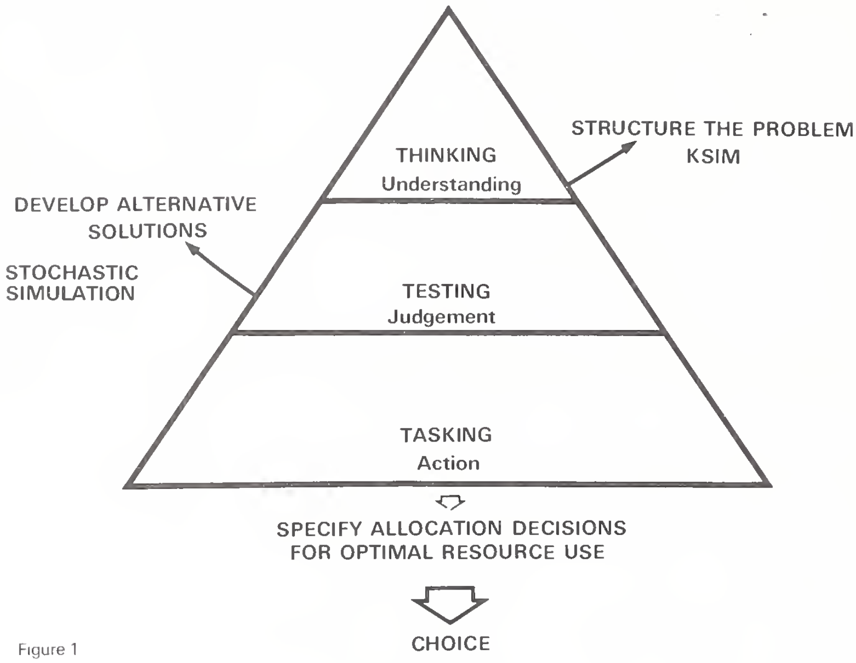

Figure 1

Table 2.--Simulation of alternatives

Policy objective	Do Nothing	STO	TRA	TRA +STO	SUB	SUB +STO	SUB +TRA	SUB +STO +TRA
Stabilization of consumption	6	5	4	3	6	5	2	1
Price	6	4	2	1	8	7	5	3
Balance of trade	1	1	3	2	1	1	5	4
Subsidy	1	1	1	1	5	4	3	2
Expected value of								
Economic benefit	5	6	1	4	7	8	2	3
Farmers' benefit	8	7	5	6	1	2	3	4
Consumers' benefit	1	2	7	4	8	5	3	6
Government subsidies	1	1	1	1	5	4	3	2
Storage authority	1	3	1	4	1	2	1	4

Conclusions

Don't use a sledge hammer when you should be thinking. This paper has attempted to show the diversity of roles that models play in facilitating understanding, judgment and action. No model is appropriate for all phases and tasks of assessment, but the repertoire of existing and emerging models allows one to choose the model that is adept in playing the needed role. The planner and publics can now select the model appropriate to the stages of their human endeavor to make better choices among technologies for an elegant and satisfying future.

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**APPLICATION OF SIMULATION MODELS TO TECHNOLOGY ASSESSMENT

by
Ted Thornton
Economic Research Service

Simulation modeling has had increased application in the past three decades. This increased application has paralleled the development of the computer. Simulation models are now widely used and are accepted tools in several disciplines. The purpose of this paper is to briefly describe simulation modeling and to discuss its application to technology assessment. By outlining the strengths and weaknesses of simulation modeling, it is hoped that those persons relatively unfamiliar with this technique will come to understand its usefulness.

The Nature of Simulation

Simulation modeling is the representation of the essential elements of some state of affairs over time. The representation may be physical, as in the case of a model aircraft used for wind tunnel tests. It may be verbal, as in a written description of some manufacturing process. For our purposes today, the representation is in mathematical and logical form for manipulation on computers.

The simulation contains only the key elements of a state of affairs. Out of the myriad of details present in any situation, the analyst selects those events and relationships which capture the important features of the situation. This process of selection can be the most challenging task for the analyst, involving his personal knowledge of the process, his consultations with members of other disciplines, and his professional judgment.

When the essential elements of a situation have been selected, the analyst quantifies them for use on the computer. Quantification itself can be a difficult process as each element must be expressed in precise mathematical or logical form. Thus the amount of land devoted to a given crop may be postulated to be some function of the amount planted in the previous period and the current price of the crop. Again, different soil loss levels for different tillage practices may be specified. The price of a commodity may be some function of the quantity of that commodity. It should be noted that not all key relationships are readily quantifiable, constituting a limitation of the analysis.

A simple model will be helpful in illustrating the nature of simulation.

Let

$$(1) \quad AC_t = f(PW_{t-1}, AC_{t-1})$$

Where

AC_t = acres planted in wheat in the present time period

PW_{t-1} = price of wheat in the previous time period

AC_{t-1} = acres planted in wheat in the previous time period

This formulation specifies that the number of acres planted in wheat in a given year is a function of the price of wheat in the previous year and the number of acres planted in

wheat in the previous year. This formulation states that the number of acres devoted to wheat can be explained by the two other variables. This, of course, is not the only formulation and illustrates the need for ingenuity and an understanding of the process to be simulated. It should again be noted that although other factors may be relevant in determining the acres of wheat planted, they must be quantifiable to be included in the model.

Now Let

$$(2) \quad FERT_t = g(PFERT_t, CASH_{t-1}, AC_t)$$

Where $FERT_t$ = amount of fertilizer purchased in present period

$PFERT_t$ = price of fertilizer in present period

$CASH_{t-1}$ = cash receipts in previous period

The amount of fertilizer purchased is postulated to be a function of the price of fertilizer, cash receipts of the previous year, and the number of acres of wheat planted in the present year. Note that AC_t in equation (2) was given a value by equation (1).

Finally, let

$$(3) \quad WHEAT_t = h\ (AC_t, FERT_t)$$

Where $WHEAT_t$ = output of wheat in present time period

This equation specifies output to be a function of the variables determined by (1) and (2). After this, the price of wheat can be estimated and then used in equation (1) of the next time period. In this way, the model iterates through time periods, drawing on the values computed in previous time periods to compute value of the present time period.

Many simulation models are extremely complex. Most readers would be able to add to this simple model to include relevant variables or to define new interrelationships. Much of the richness of simulation comes from the many avenues of approach possible and in the need for ingenuity and imagination.

When the relations have been quantified, they are fed into the computer and the model is executed. The advantage of the computer is its speed. It is able to keep track of a large number of impacts and interdependencies whereas the human mind can grasp only a limited number. The program followed by the computer, however, was humanly constructed. The machine does nothing more than exactly follow the instructions given to it.

When the task of quantification is done and the model executed, the results are checked to determine how closely they conform to reality. This can be a time-consuming process as each aspect of the model is tested. Parameters must often be modified and data recomputed to insure that the outcome stays within a reasonable range of values. Changes in certain relations also must be made and the model solved again to determine if the results conform to the expected outcomes of the changes. This testing constitutes the final step in the construction of the simulation model.

Characteristics of Simulation Relevant to Technology Assessment

A finished simulation model has several characteristics which make it an attractive tool for technology assessment. First, simulation provides the social scientist with a laboratory in which he is able to perform controlled experiments and record results. By altering parameters and data of the basic model, the scientist may trace the impacts of events throughout the system.

Simulation permits the explicit incorporation of time. Dynamic changes in the interrelationships of variables may be examined. Simulation creates a series of "snapshots" of a process. Each snapshot provides data for use in subsequent snapshots.

The process iterates for as long as the analyst desires. The time period of each iteration may correspond to the occurrence of an event or to a calendar time such as month, day, or season. This is an attractive feature for the assessment of technology as the model can reflect such things as increased crop yields or decreased costs over several time periods.

An astonishingly wide variety of situations may be simulated. Simulation models have been used in the physical sciences, the social sciences, and the behavioral sciences. Computer models have been constructed for such disparate situations as water supply management, hog farrowing, global warfare, and neurotic behavior. The range and scope of simulation is limited only by the knowledge and imagination of the analyst and by the availability of data. Because of the interdisciplinary aspect of technology assessment, simulation could provide a tool which can be used by several disciplines to consider many facets of a particular innovation or several innovations simultaneously.

Simulation is "positive" in nature. It attempts to depict and analyze a situation as it is. This is in contrast to such "normative" techniques as linear programming in which some objective function is maximized or minimized. Normative models, although of great value in many situations, can yield results which are too efficient to correspond to existing social systems.

Simulation permits the incorporation of probability events. Through random number techniques simulation is able to evaluate the impact of certain events when they are given different probabilities of happening. It is possible to enter random "shocks" into the system to simulate impacts of changes in technology or technique. Simulation can also easily handle recursive procedures. Thus, when the simulation model is started, the results are not necessarily predetermined. There can be an element of randomness in the execution of the model so that the deterministic nature of other computer techniques is avoided.

Simulation has certain characteristics which diminish its value for technology assessment. Perhaps the basic shortcoming of simulation is its difficulty in accounting for new structural forms resulting from changes in technology. Starting from a base period, simulation models iterate through subsequent time periods, assessing changes in the base structure over time. But the very essence of technology assessment is the prediction of new structure that may evolve. Whereas simulation projects the base structure over time, technology assessment often demands the consideration of entirely new structures.

It may also be difficult to adapt simulation to many items of interest because of lack of adequate data. Technology assessment is an interdisciplinary activity involving many fields and many subjects. Several of the events of interests to technology assessment are not amenable to numerical analysis. For example, the impact of a new technology on the environment would be difficult to assess because of the difficulty of measuring such elements as odor and noise. Social elements, such as impact on the family or relocation of business activity, would also be difficult to express with a number. The lack of readily quantifiable information constitutes a practical limitation to the application of simulation.

There is another closely related problem with data. Computers have the ability to digest an enormous amount of information. The construction of a simulation model is an excellent way to bring out the gaps in a data base. Even if the certain event may be quantifiable in principle, it is often the case that no data exists for it in practice. The absence of appropriate data series and the difficulty of acquiring raw data place another practical limitation on the use of simulation.

Large simulation models tend to become cumbersome. They require much time to create and maintain. A thorough-going simulation model for technology assessment would require many man-hours of work and would be unwieldly in execution. Changes in the model, although conceptually easy, often create considerable difficulty in programming. Before any simulation exercise is undertaken, it must be thoroughly discussed by all the participants involved to insure that sufficient men and time may be devoted to a continuing project.

Use of Simulation Models in Agricultural Research

Simulation models have and will continue to have an important place in agricultural research. At one extreme, models have been developed for items as small as individual plants. Such a model is useful in examining a plant's reaction to factors such as drought, fertilizer, soil type and stress. The model permits the estimation in seconds the results of which would take an entire growing season in the field.

Simulation models at the farm level are widely used by university researchers and extension personnel. Various simulation systems are now available to the farmer which aid him in making his planting decisions. These models enable the farmer to predict and choose cropping patterns under alternative lists of prices, costs, and resources.

Large-scale models have been constructed to simulate the entire agricultural sector. These models have been especially useful in highlighting interregional cropping patterns, the use of the resource base across regions, and the comparative advantage of different regions. They have been employed to predict United States farm output under various assumptions of technology, resources, and prices. A strength of these large models is their ability to incorporate all facets of the food and fiber system into a whole which may then be analyzed.

Most of the large-scale models developed in the agricultural sector were designed for purposes other than technology assessment. Most assume a given technology or, at best, minor changes in technology. Although some could be utilized for a technology assessment, they would require a complete redefinition of technical coefficients, a process which would be expensive and time consuming. The National-Interregional Agricultural Projection models developed by the projections group within the Economic Research Service, however, have been designed to explicitly incorporate changes in technology and have been used to project changes and outputs caused by technological change. More work needs to be done to create simulation models designed for technology assessment in the agricultural sector.

Conclusion

The attibutes of simulation modeling assure it a continued place in the "box of tools" used for technology assessment. Simulation provides a laboratory in which social scientists can experiment. Simulation is good for addressing complex situations which include many variables and several interrelationships. It can be applied to several fields of study. Simulation can trace events over several time periods. Finally, simulation can bring out otherwise hidden implications of a complex state of affairs.

The disadvantages of simulation center on practical consideration of time, cost, and reliable data. Simulation models tend to be big and expensive. As their strength lies in addressing complicated states of affairs, they are often inappropriate for more simple situations where standard techniques such as regression analysis and analysis of variance would be better. To successfully enter simulation, the group preparing the technology assessment should be prepared to devote a considerable amount of effort for extended periods as the models are developed and modified.

Finally, it must be stressed that the computer does not provide a magic cure for foggy problem definition, fuzzy goals, or a scanty data base. Good analysis or bad analysis, good data or bad data, it's all the same to the machine. Simulation does not circumvent the need for a reliable knowledge or data base, careful statement of the problem, and clearly stated objectives. Simulation is not a panacea but a powerful tool to complement and be complemented by creative analytical thinking.

**USE OF SCENARIO WRITING IN ASSESSING TECHNOLOGY

by
A. Barry Carr
Congressional Research Service
Library of Congress

Scenarios, particularly qualitative scenarios, are very useful instruments for dealing with technology assessment issues, because the scenario development process allows one to integrate and exercise imagination in probing the consequences of particular public policies. This paper explores the potential role of scenario writing in one type of policy analysis--technology assessment.

What Are Scenarios?

Originally a theatrical term, a scenario was a manuscript or plot outline which set forth a sequence of actions, as well as a description of characters and scences. In the fifties the word scenario was taken over by Herman Kahn and other policy analysts engaged in secret studies of the war game type at Rand. Kahn introduced the word to the public in what has become a classic to futurists, "The Year 2000," published in 1967 (2). As defined by Kahn, a scenario is a hypothetical sequence of events constructed for the purpose of focusing attention on causal processes and decision points. A scenario may be defined more completely as a consistent, well-researched, and detailed set of circumstances that is sufficiently plausible to allow the reader to understand the situations, conditions, and strategies that prevail.

Perhaps it is better to define scenarios by giving examples of how they are used. A technology assessment can be a scenario, or set of scenarios, which traces out the good and bad aspects of an oncoming technology. An environmental impact statement describes the probable or possible sequence of events and consequences attributable to some decision currently under consideration. These are examples of every day uses of scenarios. Additional short, but illustrative examples of scenarios are found in the Zentner article (8).

Scenarios can be used to answer two kinds of questions:

- How might some situation come about, step by step, from the present?
- What alternatives exist for each actor, at each step, for preventing, diverting, or facilitating the process?

Notice that the attention is on a process. A scenario is a motion picture, not a snapshot. Lest you get alternative futures and scenarios confused, an alternative future is generally used to refer to the end state, while scenario refers to the ongoing dynamic process which leads up to the alternative future.

If you think of scenarios as flow charts, don't forget that they can be used in either direction. When constructed and used in the forward direction, scenarios frequently take the form of trend projections. "If we keep going at this rate, where will we end up?" Forward directed scenarios can also be used for speculation. "I wonder what would happen if ...?" Another useful application of scenarios however, is in the opposite direction. Reverse flow charts start with a desired future, chosen from a group of alternative futures, and show the location of decision points on the path to that future. By anticipating these branching points and choosing correctly, the players can maximize the likelihood of arriving at the preselected future.

Using scenarios in technology assessment will involve thinking and writing in both directions. The process of analytic iterations in both directions is required to bring out the interactions and interdependence among the various factors under study.

The following brief listing of scenario elements might serve as a useful summary of the material just covered and set the stage for the next section. Scenarios focus on actors, who when involved with events, are faced with choices and must make decisions which lead to consequences. The cycle repeats itself throughout the scenario.

How Are Scenarios Used--And Misused?

"Mankind's dilemma is that our knowledge is about the past and our decisions are about the future" (quote from Ian Wilson of General Electric). We frequently cannot forecast the future with great confidence. However we can use multiple scenarios to cover the expected ranges in certain trends and events. Scenarios do not eliminate uncertainty, but rather help explore it, so that policy can be made with a full awareness of the dimensions of uncertainty about the future. This process, when used to identify and deal with decisions that must be made in the management of technology, is called technology assessment.

Analysts traditionally complain about the lack of good data. Without good data our models cannot be validated and our sophisticated mathematical techniques bog down. But many analyses have suffered far more from a lack of theory than a lack of empirical data. Analysts too frequently rush through the "thinking" stage of the assessment in their hurry to get to the data analysis. When the data analysis is based on a poorly structured theoretical base or when the dimensions of the problem are not fully specified, the outcome is usually a mindless exercise in manipulating numbers. Such failures not only waste research resources, but also confuse policymakers and the general public.

For these reasons scenario writing is most useful when begun at the very outset of a policy analysis. The first attempt at writing scenarios will force the analyst to look at the future in concrete terms. Scenario writing calls attention to the large range of possibilities that must be considered in the analysis. At the same time, the analyst is forced to make the assumptions more explicit. In short, the first set of scenarios provides a structural framework for the analysis which is crucial in building the formal analytical model.

The presentation of quantitative results of a technology assessment to the public or other decisionmakers can usually be done best in a scenario format. Some have called this the didactic or teaching phase, as contrasted with the heuristic and analytic phases just discussed. Unfortunately some analysts stop short of proper presentation. Tables of data, with years across the top and variable names down the stub can describe some of the scenario elements mentioned earlier (actors, events, choices, decisions, and consequences). However a user's comparison of scenarios involves tradeoffs, and the major assessment task is to integrate the impacts (good and bad) such that the user can aggregate the range of possible outcomes into an ordered preference set.

The principal concern in designing scenarios, as with all other aspects of the technology assessment, should be relevance--to the users and to the issues. Each aspect of the scenario should be considered carefully and tested for relevance:

- the type and amount of data presented,
- the type and number of actors (participants), events and choices considered,
- the time frame of the analysts,
- the level of focus (micro or macro), and
- how many scenarios to use.

A basic principle in scenario writing is "keep it simple". Needless complexity adds confusion and reduces utility. With respect to the size and level of detail of the scenario, strive to avoid needless complexity and the confusion which results.

The time period of the scenario should correspond closely to the planning horizon implied by the technology being assessed. This might be 100 years for a forestry technology, 50 years or less for a resource development technology, or 10 years or less

for a cropping system technology. Some scenario writers are preoccupied with magic numbers like the year 2000. Regardless of how far ahead a scenario looks, it should not ignore the present and all segments of the time path from the present to the future.

The number of scenarios used should be minimal. Computers have the capability of producing an infinite number of scenarios, each slightly different from others in one variable or the other. However most users have great difficulty in keeping track of large numbers of scenarios at one time. When limiting the number of scenarios, it is often useful to use one as a baseline scenario (e.g., what might occur in the future without the adoption of the technology under study). One or more additional scenarios can be used to explore the consequences of one or several rates of adoption of the new technology. This kind of spread will at least demonstrate how much difference, if any, exists in the futures. Later scenarios can explore more relevant areas of the spread.

Usually it is unwise to label any scenario as "the most likely" or "most probable". In view of the large number of possible future outcomes, each and any specific outcome has a low probability of occurrence. Experience has shown that users are easily distracted by probability labels, such that all but the most probable scenario is ignored.

The process of obsolescence begins the moment most scenarios are completed. Scenarios must be kept current to be useful. Updating can sometimes be accomplished by replacing key data tables, graphs, and charts, provided the scenarios were constructed so as to permit easy replacement of these items.

The fundamental criteria for judging the quality of a completed set of scenarios should be credibility. The scenarios must be linked to the real world, they must be plausible (believable) at each step, and internally consistent. Scenarios based on some miraculous discovery are sometimes entertaining, but are usually not considered plausible. Don't confuse plausibility, however, with predictive accuracy. Most scenarios are intended to discuss what could happen, not what will happen. The scenarios must also walk the thin line between intelligibility (being easy to understand) and utility (having enough detail to create an image that people can perceive as desirable or undesirable).

How Have Scenarios Been Used In Technology Assessment?

In the summer of 1975 the Office of Planning and Evaluation (OP&E) of the USDA published a policy study titled, "Alternative Futures for U.S. Agriculture" (5). This study looked at three different agricultural systems being supported by various advocates:

- A maximum efficiency, free enterprise industry characterized by fewer and larger farms, and based on accelerated rates of productivity increases;
- A supply control future characterized by Government programs to stabilize production and prices, and based on trend rates of productivity increases;
- A small farm agriculture which would permit the maximum number of farms, and based on a reorientation away from capital intensive, large-scale technology.

The scenarios began in 1972 and ended in 2010. Each scenario contained a description of the policy instruments (programs) required to achieve the desired future. The impacts, costs, and consequences upon farmers, farm laborers, rural towns, domestic consumers, foreign consumers, Government expenditures, natural resources, and environmental quality were discussed. The report was rushed to print with only limited review when OP&E was abolished and its functions transferred to other units within the USDA. How well do these scenarios stand up when examined by the criteria of credibility, intelligibility, and utility? The debate that has occurred since their release has revealed some shortcomings in terms of the assumptions made and the impacts ignored. Nevertheless, the study did exhibit a process in futures analysis of policy sensitive phenomena. The results of the analysis are summarized in Appendix A.

The Federal Energy Administration made headlines last year with its "Project Independence Report" (1). This report laid out three scenarios of a U.S. energy future in 1985. One scenario was based on no Government action; one was based on reducing demand by use of conserving technology and Government regulation; and the other was based on stimulation of energy supplies by use of production technology and Government action. These are an example of using scenarios to lay out the extremes of an issue. The report appears to be a success in terms of providing a basis for debate about U.S. energy policy.

Stanford Research Institute (SRI) conducted a study under contract with the Environmental Protection Agency (EPA) on the subject of pesticide policy (3). The objective of the report was to provide EPA with a set of alternative future forecasts for use in the planning of pesticide policy. Although 10 scenarios were presented, they could have been classified into three basic alternative futures. The scenarios were differentiated on the basis of different trends for energy, climate, food production, and social values through three time frames: 1980, 1990, and 2000. Policy implications were derived by examining specific policy issues provided by EPA in the context of each of the scenarios. The SRI report was the most comprehensive set of scenarios used in an agricultural policy analysis to date. It was a valuable reference for anyone engaged in technology assessments of an agricultural nature.

The best sellers in the scenario field seem not to come from the pens of government bureaucrats, but rather from the academic world. Malthus wrote his "Essay on the Principle of Population" in 1978. An MIT team, led by Dennis Meadows, issued "Limits to Growth" in 1972, a study of aggregate impacts of technology coupled with population and economic growth (4). These and other scenarios are included in the bibliography at the end of this paper.

Summing Up

This paper is intended to make the job of working with scenarios more productive and easier to do. Scenarios are a way of exploring and analyzing, not predicting, the future. Good scenarios can be used by policymakers as a guide for deliberation and a tool for analysis of alternative technological futures.

What relevance does all of this have to the work of the research analyst? Most likely he is at liberty to choose whether or not to include scenario writing in his work. But one can hardly choose to ignore scenarios that are being written by others. These scenarios, if they are successful, generate debate about the issues. Research analysts are asked to assist in this debate, to interpret and evaluate this material.

Technology assessment has come a long way from the methods of our ancestors. In ancient Rome, divination of the future was a function of the College of Augurs, which was still functioning as late as the fourth century after Christ. Ranging in size from 4 to as many as 16 members, the augurs worked principally in Rome itself, advising senators, generals, an emperors. Their principal method was to ascend a hill at midnight and seek omens in shooting stars, clouds, storms, and the flight of birds. Other techniques the augurs employed included the casting of lots and the examination of the entrails of animals that had been sacrificed for the purpose (8). How will future generations view the use of technology assessment in the 20th century?

Appendix A - Projected Attributes Of Alternative U.S. Agricultural Futures

Selected attributes	Base period (1967-69)	2010 Supply management	2010 Maximum efficiency	2010 Small farm
Number of farms (thousands)	2,728*	1,500	950	2,100
Sales over $40,000	222*	600	950	450
Sales under $40,000	2,506*	900	0	1,650
Farm labor inputs (persons, 000)	4,749	2,800	2,650	2,900
Hired labor	1,214	800	1,600	200
Family labor	3,535	2,000	1,050	2,700
Capital ($ Billion)				
Assets	323	560	550	540
Liabilities	58	200	200	180
Owners Equity	265	360	350	360
Tenure of operators (percent of total):				
Full owners	62	60	42	74
Part owners	25	36	52	25
Full tenants	13	0	0	0
Managers	1	4	8	1
Net Farm Income				
Total ($ Million)	15,234	41,990	45,400	33,900
Per farm ($)	5,584	27,993	47,789	16,143
All Income per farm ($)				
Sales less than $2,500				
Net farm income	1,023	700	---	1,400
Nonfarm income	6,335	19,000	---	26,000
Total	7,358	19,900	---	27,400
Sales $2,500-$39,999				
Net farm income	5,884	10,000	---	14,000
Nonfarm income	3,468	11,000	---	11,000
Total	9,352	21,000	---	25,000
Sales $40,000 & over				
Net farm income	27,118	61,000	47,800	32,000
Nonfarm income	5,041	11,000	10,000	11,000
Total	32,159	72,000	57,800	43,000
Consumer Food Expenditures				
U.S. Total ($ Billion)	94	192	189	191
Per capita ($)	503	641	632	636
Agriculture Foreign Trade ($ Million)				
Exports	6,274	19,000	17,100	9,900
Imports	4,680	12,600	12,600	9,800
Balance	1,594	6,400	4,500	100

* 1969 only.

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** A DELPHI TECHNIQUE FOR FORECASTING THE IMPACT OF EMERGING TECHNOLOGIES IN MEAT PACKING AND PROCESSING

by
Douglas W. McNeil and Yao-Chi Lu
Economic Research Service

The purpose of this paper is to briefly discuss a Delphi forecasting technique, summarize its strengths and weaknesses as a research tool for analyzing the future, and illustrate how it may be applied to identify and evaluate the impact of emerging technologies in the meat packing and processing industries.

Delphi Forecasting

Delphi forecasting is a technique for systematic solicitation and development of a consensus of expert opinion about future events (1, p. 34; 4, p. 63). A conventional paper and pencil Delphi forecast is initiated by a questionnarie designed by a small monitor team which requests estimates of a set of uncertain quantities (such as the dates at which technological possibilities will be realized) from a larger respondent group of experts on a subject. The results of the first round are summarized and fed back to the respondents with a request to revise the first estimates where appropriate. On succeeding rounds, those individuals whose answers deviate markedly from the group's consensus range are requested to justify their estimates. A summary of these justifications is fed back to the respondents and counterarguments are elicited. In the following rounds the counterarguments are in turn fed back and additional reappraisals are collected (4, p. 65). The process usually continues through a number of rounds until some consensus is reached, or until the underlying reasons for disagreements among the experts have been explored and evaluated. This feedback process serves to stimulate the respondents to consider points which they had inadvertently neglected, and to give more weight to factors they had dismissed on first thought as unimportant (1, p. 34). To eliminate the delay caused in summarizing each round, a conference or "real-time" Delphi utilizing a computer programmed to compile the group results may be substituted for the paper and pencil approach.

Two basic assumptions underline Delphi forecasting inquiries. In situations of uncertainty, due to incomplete information or inadequate theories, expert judgment can be used as a surrogate for direct knowledge; also, a consensus obtained by pooling the judgments of a group of experts is preferable to the judgment of a typical member of the group. While projections about future technologies do not lend themselves to precise measurement, it is reasonable to assume that they can benefit from expert judgment. Since individual experts may hold incorrect opinions, it is logical to seek increased accuracy through the opinions of a collection of experts. It is assumed that a representative statistic of the experts' opinions will be more accurate than the opinion of the average expert, and individual bias and misinformation will be corrected for by pooling group opinion. Delphi forecasting methodology was developed with this purpose in mind (4, p. 64).

Delphi is particularly well suited for developing expert opinion consensus about future technologies and their impacts. By preserving the anonymity of individual responses, Delphi reduces the influence of psychological factors which often bias the outcome of face-to-face committee activities, e.g., the reluctance of individuals to

take a position before it is known which way the majority is headed, the unwillingness to abandon publicly expressed opinions, the tendency of domineering or outspoken persons to take over, the bandwagon effect of majority opinion, etc. Delphi systematically controls feedback to minimize these psychological factors and develop a consensus of expert opinion about future events.

Delphi has several other advantages. It may be employed effectively when the individuals needed to examine future events have no history of adequate communication, when more individuals are needed than can effectively interact in a face-to-face exchange, or when time and cost make frequent group meetings infeasible. Finally, as will be seen in the next section, when integrated with trend extrapolation, the Delphi forecasting process forces the experts to relate their intuitive models or judgments of the future to actual rather than perceived historical trends as they interact to reach a consensus (4, p. 67).

The Delphi forecasting technique also has several limitations. Delphi should not be interpreted as a device that produces "truth about the future". The Delphi forecasting method is designed to produce consensus judgments in uncertain fields; it would be a mistake to consider such judgments as complete or precise descriptions of the future (4, p. 74).

Since results from the observation of small Delphi groups may be subject to considerable "noise", use of the median of the individual responses (which is not sensitive to large dispersions even if they are one-sided) is basic to most Delphi evaluations. But the relationship between group size and group performance is not clearly understood. Brockhoff found no general positive relationship between group size and group performance (2, p. 320). Dalkey found that average group error drops rapidly as the number in the Delphi group is increased to about 8 or 12, but after reaching about 13 to 15 the average group error decreases very little with each additional member. Thus, Fusfeld and Foster concluded that a Delphi user could feel fairly safe in choosing a group size of 10 to 12 (4, p. 70).

There are several other pitfalls to be avoided when carrying out a Delphi forecast. The monitor must be careful not to impose his views and preconceptions of the future upon the respondent group by overspecifying the structure of the Delphi and not allowing for the contribution of other perspectives related to the future. Misinterpretations resulting from poor techniques for summarizing and presenting the group response can also be a problem. If disagreements are not explored, dissenters may become discouraged and drop out, generating an artificial consensus. The time-consuming nature of the feedback process is also a fact that must be recognized when a paper and pencil approach is utilized.

Application to the Meat Packing and Processing Industries

The application which follows demonstrates how Delphi forecasting may be used to identify and evaluate the impact of emerging technologies in the meat packing and processing industries. The Delphi inquiry will be conducted in two stages. In the first stage a paper and pencil Delphi will seek consensus from a group of meat packing and processing technology experts about the identity of emerging technologies with great impact potential for the meat packing and processing industries during the next 25 years. The group will include technology experts representing nine large meat packing and processing firms selected by the American Meat Institute, the largest trade association of meat packers and processors.

A comprehensive search of the literature was made to provide information for designing the initial questionnaire. On the basis of information gleaned from the literature the following 10 phases of the meat packing and processing industries and related areas were chosen for examination: production of meat animals, procurement of meat animals for slaughter, slaughter and dressing of meat animals, cutting meat, processing meat products, preservation of meat products, packaging of meat products, distribution of meat products, utilization of meat byproducts, and development and adoption of new and improved meat packing and processing machinery, tools, and equipment.

To help stimulate the respondents' imaginations, emerging technologies potentially affecting each phase are listed on the initial questionnaire. Of course in succeeding rounds, respondents are invited to make additions or revisions to these initial lists. Respondents are asked to indicate the impact potential of each event listed, as well as its likelihood of occurring in the next 25 years. Information on the phases of the meat packing and processing industries most susceptible to technological change and the identity of the specific emerging technologies with the greatest impact potential will be obtained through successive rounds of the Delphi process.

Once the emerging technologies with the greatest impact potential have been identified, phase two of the Delphi forecast will begin. A combination of informal interviews and written questionnaires will be used to project the impact of each emerging technology on the value of shipments, the cost of livestock and raw materials, the amount of labor, and the amount of capital required to the year 2000.

Respondents will be confronted with graphs showing the historical patterns of these variables from 1947 to the present, as well as extrapolated trend line projections to the year 2000. Each will be asked to agree or disagree with the trend projections. Those who disagree will be asked to explain why and to draw in their own trend projections. Over several rounds, adjusted trend line projections for each variable can be developed.

Next the respondents will be asked to evaluate the impact not captured in the adjusted trend line projections of those emerging technologies identified as having the greatest impact potential. Respondents will be asked to indicate (1) the likelihood of the occurrence of each technology by the year 1980, 1985, 1990, 1995, and 2000; (2) the percent of total output affected by adoption 10 and 20 years after the introduction of each technology; (3) the maximum percent of output affected by adoption; and (4) the magnitude of the impact(s) on the value of shipments, cost of livestock and raw materials, the amount of labor, and the amount of capital required.

A subjective probability distribution indicating the probability of the occurrence of each new technology in year t can be derived from the likelihood information. While the adoption profile may vary among different technologies, it is assumed for each technology that the rate of adoption will be slow in the initial introduction stage, increase at an exponential rate as more packers and processors are attracted to the new technology, and finally decline and gradually approach a ceiling as a saturation rate is reached. It is also assumed that the adoption profile will remain the same regardless of when the technology becomes commercially available. Information from a consensus of expert opinion about the percent of output affected by adoption allows estimation of the parameters of an adoption profile of the following form which has the desired properties noted above:

$$A_i = \frac{k}{1 + be^{-ai}}$$

where

A_i = the adoption profile, i.e., the percent of output affected in the ith year after adoption;

k = the maximum percent of output affected by adoption;

and a and b are parameters to be estimated.

The expected value of the impact, I_{t+i}, (on the value of shipments for instance) in the ith year of adoption of a new technology can be calculated as follows:

$$I_{t+1} = P_t \, A_i \, v \, V_{t+i}$$

where

P_t = the probability of the technology occurring in year t;

v = the magnitude of the impact on the value of shipments (assumed to be a constant percent of V_{t+i});

and

V_{t+i} = the value of shipments in the ith year of adoption.

The expected value of the impact, I_{t+i}, can be derived for each technology and used to "shock" the adjusted trend line of each variable affected.

The final projections of the value of shipments, cost of livestock and raw materials, amount of labor, and amount of capital required can be combined to compute productivity indexes for the meat packing and processing industries. A measure of net output (value added) is obtained by subtracting the cost of livestock and raw materials from the value of shipments. The sum of capital and labor requirements provides a measure of inputs used. An index of productivity can subsequently be derived by dividing an index of net output produced by an index of inputs used.

Comparative productivity indexes can be computed before and after the effects of the emerging technologies are accounted for. If experts can provide estimates of the expected cost of developing and adopting the technologies, an expected rate of return for each technology can be computed. Additional analysis will be developed to evaluate the attendant welfare effects on livestock producers, meat packers and processors, and consumers of meat products.

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** IMPACTS OF EMERGING TECHNOLOGIES ON AGRICULTURAL PRODUCTIVITY PROJECTIONS

by
Yao-Chi Lu
Economic Research Service

Technological change has been one of the major driving forces behind economic growth. Unfortunately technology is also held accountable for generating wastes that pollute our environment by destroying or harming ecology, ruining the esthetic quality of the countryside, rivers, and shoreline, and harming human health. Technology assessment has resulted from public concern over these negative impacts of technology (2).

While recent studies of technology assessment are concerned with the total impacts of technology on social, economic, ecological, technical, and political environments, this study will deal with only the impact of technology on agricultural productivity.

A combination of statistical methods, simulation, and judgment will be used in this study. Statistical methods will be used to obtain the parameters for the simulation model, and the possible paths of productivity growth will be simulated under alternative assumptions. The Delphi technique and the relevance tree method will be employed to obtain soft data on emerging technologies in agricultural production.

Construction of Productivity Change Simulation Model

The first step in constructing a productivity change simulation model is to establish functional relationships between productivity change and the factors responsible for the change. Productivity change is the end result of the interactions of many factors. Changes in technologies, improvement in the management skill and health of farmers, changes in the prices received and paid by farmers, increases in the level of educational attainment of farmers, public policy and programs, weather, and environmental constraints on production all contribute to productivity change.

However, the most important factor contributing to long-term productivity growth is technological change, and the development of new technologies depends upon investment in scientific research.

After a new technology is developed, it must be adopted by farmers in order to effect productivity. The rate of adoption depends upon a number of factors, including extension activities and the level of educational attainment of farmers. Extension activities disseminate technical information to farmers, and the increased level of educational attainment of farmers is associated with increased farmer ability to cope with the managerial demands of increasingly complex technologies.

Another important source of productivity change is the weather. Not only does weather physically affect productivity in agriculture, but weather variability may also influence the rates of adoption of new technologies. A farmer faced with a relatively high degree of randomness in precipitation and temperature would be expected to fully employ a new technology more cautiously than a farmer operating under relatively stable weather conditions, since the latter can more readily assess the costs and benefits of the new technique.

As it is impossible and impractical to include all the sources of productivity change into a mathematical model, only some of the more important variables which are observable and measurable are included. For purposes of developing the simulation model, it is hypothesized that the rate of productivity change depends upon production-oriented

research and extension (R&E) expenditure, the level of educational attainment of farmers, and weather.

Among these hypothesized forces, R&E expenditure is the variable which the policy-maker can most easily control to influence the future path of productivity growth. The effect of a research investment upon productivity cannot be realized immediately since some time is required to conduct the research, disseminate the new knowledge, and to adopt the new technology. Dissemination of new knowledge starts when the research is completed. As more and more farmers adopt the new technology, the annual effect of R&E on productivity increases. It is likely that effect on productivity will decline sometime after reaching a peak because the technology becomes obsolete or depreciates in value due to biological decay, changes in relative input prices, or development of superior inputs (4). Therefore, it is hypothesized that the ensuing effect of an R&E investment in a single technology on agricultural productivity follows a time form of an inverted U shape.

Estimation of the Parameters of the Simulation Models

To estimate the parameters of the simulation model, data for the productivity index, R&E expenditures, the education index, and weather index were assembled from 1939 to 1972. The Almon (1) distributed lag method and Durbin's (3) two stage procedure were used to estimate the parameters. The results indicate that a 1-percent increase in the R&E expenditures will raise the agricultural productivity a cumulative total of 0.037 percent. This estimated gain in productivity is distributed over 13 years about as follows: 0.0009 percent the first year, increasing gradually to 0.0037 percent the seventh year, and then declining to 0.0009 percent the thirteenth year.

The level of educational attainment of farmers and weather also play an important role in productivity change. The results indicate that a 1-percent increase in the education index will increase productivity about 0.8 percent, and a 1-percent change in the weather index will change agricultural productivity by 0.0002 percent.

Simulations of Agricultural Productivity

After establishing the simulation model it is possible to project productivity by projecting its sources. A logistic curve was fitted to the education index data from 1939 to 1972, and future values of the education index were extrapolated from the logistic curve. Although no attempt was made to predict the long-term weather trend, the variability of weather was simulated so that its impact on agricultural productivity could be evaluated. Based on the weather index data from 1939 to 1972, a normal distribution was selected to approximate the frequency distribution of the weather index. The estimates of the parameters of the normal distribution were then incorporated into a computerized model to simulate future weather indexes.

To understand what possible future productivity growth may be achieved by different levels of real R&E expenditures, five projections were developed to represent five possible growth rates of R&E expenditures.

(1) Continue the observed rate of growth during the 1939-44 period: -2.23 percent a year;
(2) Maintain a zero rate of growth;
(3) Continue the observed rate of growth during the 1939-72 period: 3 percent a year;
(4) Continue the average rates of growth during the 1956-58 period: 10 percent a year;
(5) Maintain the observed rate of growth during the 1956-58 period: 10 percent a year.

The projected values of the education index, the weather index, and the growth rates of R&E expenditures were fed into the simulation model to project future agricultural productivity growth. The results of projected productivity indexes under average weather conditions and for the five assumed growth rates of R&E expenditures are presented in table 1. Productivity growth under assumed R&E growth rate 3 is judged the most likely alternative future. As shown in table 1, if no radical changes in the funding patterns of R&E expenditures occur in the future, it is most likely that the productivity index in the year 2025 will be 174.18 under average weather conditions.

By comparing the productivity growth under differing R&E growth rates, it seems that agricultural productivity is insensitive to increased R&E expenditures. This low sensitivity is partially due to the magnitude of the unit of measurement of the aggregate productivity index. A one-point increase in productivity seems not very impressive, but it means about $343 million (in 1957-59 dollars) of output. Besides, a large portion of present agricultural research activity is devoted to maintenance of the present stock of knowledge in the face of new environmental and institutional constraints.

Table 1.--Projections of U.S. agricultural productivity, 1980-2025

Year	Projected productivity index under alternative R&E growth rates				
	1	2	3	4	5
1980	114.37	114.47	114.61	114.80	114.93
1985	120.19	120.60	121.21	122.00	122.57
1990	125.73	126.63	127.95	129.67	130.94
1995	131.19	132.61	134.73	137.51	139.56
2000	136.52	138.53	141.51	145.45	148.38
2005	141.71	144.33	148.25	153.45	157.34
2010	146.73	150.00	154.91	161.48	166.43
2015	151.55	155.50	161.47	169.51	175.60
2020	156.14	160.81	167.90	177.51	184.82
2025	160.49	165.91	174.18	185.44	194.07

Identification of Emerging Agricultural Technologies

The above productivity index projections were made under the assumption that forces which shaped productivity trends in the past will continue through the year 2025. Investment in R&E will be increased at an assumed specific rate, and the level of educational attainment will increase following the logistic curve. In order for productivity to follow the projected course, the specified rate of increase in R&E expenditures must be invested to develop new technologies continually and to disseminate the results to farmers. Therefore, the projected productivity indexes can be assumed to capture the effects of most of the new technologies. However, it may not capture the effects of some technological breakthroughs.

If a technological breakthrough occurs, it will produce a shock in the agricultural production process and cause the projected productivity course to shift upward. Will there be technological breakthroughs in agriculture by the year 2025? What new technologies will have marked impacts on agricultural production? What is the likelihood of a particular technology becoming available for adoption by a specific year? How fast can this technology be adopted by farmers? How big an impact will the new technology have on crop and livestock production? To answer these questions a study was conducted in 1974 using a modified Delphi and relevance tree methods in cooperation with Resources for the Future and the Ford Foundation. Existing literature pertaining to emerging technologies was reviewed, and researchers in the Agricultural Research Service, the Cooperative State Research Service, and the Cooperative Extension Service were interviewed.

The following twelve emerging technologies were initially identified as having significant impacts on agricultural productivity: (1) enhancement of photosynthetic efficiency, (2) water and fertilizer management, (3) crop pest control strategies, (4) protected cultivation or greenhouse agriculture, (5) multiple and intensive cropping, (6) reduced or minimum tillage, (7) bioregulators, (8) new and improved hybrids, (9) bioprocessing, (10) antitranspirants, (11) development of plants to withstand drought and salinity, and (12) twinning. Most of the researchers interviewed believe that many of the emerging technologies will simply maintain the current trend and thus their impacts are already captured in the base projections. Only three technologies--twinning, bioregulators and photosynthesis enhancement are considered by the researchers to have unprecedented impacts on agricultural productivity.

Enhancement of photosynthetic efficiency includes: (a) improvements in the process by which living plants form carbohydrates through genetic selection, physical modification, and chemical modification, (b) enhancement of biological capacity of living plants to absorb nitrogen for protein synthesis, and (c) enhancement of the growth rates of agronomic plants through elevation of atmospheric levels of carbon dioxide. Bioregulators are natural and synthetic compounds. When applied at the preharvest stage, they will enhance ripening and the ability to harvest mechanically certain fruits and vegetables and when applied at the postharvest stage, they will prolong shelf life and reduce cooling costs. There are three major lines of inquiry into twinning in beef cattle: (1) breeding and selection of livestock for desirable genetic traits, (2) multiple ovulation through hormonal control, and (3) embryo transfer. These three technologies are included in the impact analysis to modify the productivity projections.

Evaluation of the Impacts of Emerging Technologies

To analyze the impacts of the three technologies on agricultural productivity, additional information was obtained on each technology such as the likelihood of each technology becoming commercially available in specific future years, the rate and pattern of possible adoption, the specific crops or livestock which affected by its impacts, and the net increases in the dollar values of the output of the affected crops or livestock. This increase represents the value of additional output a new technology would permit net of increased cost of using that technology.

The estimated impacts of the three technologies on agricultural productivity for the United States are shown in table 2. The base projection of the productivity index under R&E growth rate 3 is reproduced in column 2. The expected values of the productivity indexes adjusted for impacts derived from adoption of twinning, bioregulators, photosynthesis enhancement, and all three technologies combined are listed in columns 3 to 6. Column 7 shows the projection of the productivity index if all three technologies became available for adoption with certainty in the earliest year mentioned either by agricultural researchers interviewed or the literature. This represents the most optimistic projection.

For the year 2025, the projected base productivity index for the United States under R&E growth rate 3 is 174.18, and the expected values of the productivity index adjusted for the impacts of twinning, bioregulators, and photosynthesis enhancement are

Table 2.--Impacts of emerging technologies on agricultural productivity

Year	Base Productivity Index Projections	Expected Values of Productivity Indexes Adjusted for Impacts of: Twinning	Bioregulators	Photosynthesis Enhancement	All Three Technologies	Maximum Value of Productivity Index Projection
1980	114.61	114.61	114.61	114.61	114.61	115.60
1985	212.21	121.21	121.28	121.21	121.28	123.98
1990	127.95	127.95	128.48	127.95	128.49	133.08
1995	134.73	134.82	136.45	134.80	136.61	144.68
2000	141.51	142.80	144.95	141.92	146.65	157.26
2005	148.25	152.69	153.29	149.43	158.91	170.65
2010	154.91	162.75	161.01	157.46	171.40	184.06
2015	161.47	171.82	168.14	166.28	183.30	197.79
2020	167.90	179.91	175.02	176.26	195.39	209.45
2025	174.18	187.44	181.75	187.41	208.24	220.18

187.44, 181.75, and 187.41, respectively (table 2). The net gains in the productivity indexes due to the impacts of the above three technologies are 13.26, 7.57, and 13.23, respectively. An estimated total increase of 34.1 points in productivity due to all three technologies can be obtained by summing the net productivity gains due to the three technologies. This 34.1-point gain in productivity has an estimated value of $11,678 million in 1957-59 constant dollars. 1/

Summary

Although many factors contribute to productivity change, only public research and extension expenditures, the level of educational attainment of farmers, and weather were included in explaining changes in productivity. In estimating the contributions of research and extension expenditures to agricultural productivity, it was hypothesized that the effect of an investment in research and extension on agricultural productivity is felt over a long period of time and that the time form of the effects follows an inverted U shape.

From the results of regression analysis, a productivity change model was formulated. The education index was extrapolated through the year 2025 assuming a logistic curve. From historical data of the weather index, the normal distribution was adopted to simulate future weather conditions. Based on data of the rate of growth of research and extension expenditures from 1939 to 1972, five projections were developed. The projected values of the above three independent variables were fed into the productivity change model to simulate future rates of productivity change.

To evaluate the effect of emerging technologies in the projections, twelve technologies were initially identified as having marked impacts on agricultural productivity. However, most researchers interviewed believed that many of the emerging technologies would maintain the *status quo* and their impacts would already be captured in the base projections. Only three technologies--twinning in beef cattle, bioregulators, and photosynthesis enhancement--were considered by the researchers to have unprecedented impacts on agricultural productivity. These were the three technologies included in the impact analysis.

1/ The calculation of these numbers is based upon the implicit assumption that there are no negative effects of the technologies upon productivity, production, prices, and consumption of crops or livestock not directly affected by the technologies.

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APPENDIX

Time Series Data, 48 Contiguous States

Year	USDA Productivity Index (1967=100)	Educational Attainment Index	Weather Index	Public Sector Research and Extension Expenditures Affecting The Technological Environment (Current Dollars 000) ARS	ERS	SAES	SCS	CES	Total
1929 ...				7015	267	14976	0	12988	35246
1930 ...				8219	326	16162	0	13670	38377
1931 ...				9384	354	16264	0	13871	39873
1932 ...				9910	450	16123	0	12582	39065
1933 ...				8049	351	14097	0	11491	33988
1934 ...				7002	297	13312	0	13017	33628
1935 ...				7367	328	13700	0	11105	32500
1936 ...				8466	343	14876	4851	16658	45194
1937 ...				8606	342	15967	19119	16193	60227
1938 ...				9116	156	17923	19108	16437	62740
1939 ...	60.00	94.6	98.1	9284	215	18662	19224	16743	64128
1940 ...	62.00	96.0	86.1	9101	1062	19211	19580	16697	65651
1941 ...	64.00	97.4	107.1	8848	1577	20227	15351	16866	62869
1942 ...	69.00	98.8	111.8	9250	1340	22181	18490	13706	64967
1943 ...	68.00	100.2	101.7	9137	1165	21578	20562	13898	66340
1944 ...	69.00	101.6	101.0	8960	1168	23182	21033	13978	68321
1945 ...	70.00	103.0	106.8	10189	1044	24221	26297	14679	76430
1946 ...	72.00	104.4	100.8	11525	1440	28546	31806	18036	91353
1947 ...	70.00	105.8	96.5	13733	1267	35434	41617	21415	113466
1948 ...	76.00	107.2	118.4	14767	1011	44129	36471	23943	120321
1949 ...	73.00	108.6	93.9	15858	1104	50043	45085	25855	137945
1950 ...	73.00	110.0	102.3	18978	1367	58475	49676	28758	157254
1951 ...	73.00	113.0	100.9	19187	1356	62794	49831	29323	162491
1952 ...	76.00	116.0	95.8	19879	1256	69536	52050	30866	173587
1953 ...	77.00	118.0	95.6	21873	851	72356	54682	30200	179962
1954 ...	78.00	119.0	96.1	23177	863	80297	54268	31668	190273
1955 ...	81.00	120.0	104.2	24983	998	87831	52062	35792	201666
1956 ...	82.00	121.0	89.4	27648	1361	100091	55599	38848	223547
1957 ...	83.00	122.0	103.2	37967	1421	108989	59141	42311	249829
1958 ...	89.00	124.6	113.8	42652	1570	124765	66357	46510	281854
1959 ...	90.00	129.5	96.0	45123	1589	130455	71825	47170	296162
1960 ...	93.00	129.2	108.2	46390	1579	141055	75014	48336	312374
1961 ...	94.00	131.0	102.3	53034	3175	145432	81185	51152	333978
1962 ...	95.00	133.0	97.4	56261	3277	156222	88006	56659	361325
1963 ...	98.00	134.0	105.1	58624	3079	165847	93260	59885	380695
1964 ...	97.00	135.0	101.2	63277	3360	187008	96512	62852	413009
1965 ...	100.00	138.8	104.3	75945	4788	205864	103165	66685	456447
1966 ...	97.00	142.6	101.4	86742	5069	224722	108475	72621	497629
1967 ...	100.00	146.4	100.5	93037	5899	234021	111265	75785	520007
1968 ...	101.00	150.3	102.7	101308	5718	264457	113974	80202	565659
1969 ...	101.00	153.7	103.8	107742	6576	278553	117697	86772	597340
1970 ...	101.00	157.2	96.9	100037	6854	301118	131094	105410	644513
1971 ...	108.00	161.6	105.0	119020	7625	324592	138874	120246	710457
1972 ...	109.00	166.0	105.1	126032	7622	348266	166830	130263	779013

UTILITY OF INTERINDUSTRY INPUT-OUTPUT MODELS IN STRUCTURING AND MEASURING IMPACTS OF NEW TECHNOLOGY

by
Gerald E. Schluter and Thomas A. Niles
Economic Research Service

Input-output models are at the same time very weak and very powerful as tools for technology assessment. They are very weak because the relationships expressed within input-output models are averages, and to compound the problem, often these averages are averages of broad economic sectors. This is unfortunate because the technology assessment problems are often presented in terms of marginal effects, and often quite specific industry or firm impacts. Thus, input-output models should be supplemented by other methods and by a healthy dose of professional judgment.

On the other hand, the very thing being studied, technological innovation, has made the use of input-output models indispensable to a complete assessment. The nature of a technically advanced economy is inherently complex and interrelated. The more highly interrelated the sectors of the economy, the larger the number of indirect effects one could expect from introducing a change in production techniques in one sector. Under these situations the availability of an input-output model is invaluable for identifying the location as well as the expected magnitude of these indirect effects.

Input-output models can potentially provide useful information on impacts of a new technique at two stages in the process: the effects of the investment required to implement the technique, and the effects on the economy after implementation. These two potentials first will be discussed and then some broader macroeconomic issues will be reviewed.

Basic Procedure and Illustrations

Most innovations require a certain level of economic activity to bring the procedure into production. Let us assume this is some type of capital investment activity, such as a new machine or structure. The firm producing this machine or constructing this structure must buy goods and services from other firms in the economy, who, in turn, must do likewise, and we observe a whole sequence of supporting economic activity required to make this new machine or structure available. The accumulated value of the sequence can be estimated with the total requirements matrix of an input-output model. If Y represents the capital investment activity and $(I-A)^{-1}$ represents the total requirements matrix, then the vector X, the level of total economic activity needed to supply the capital investment, can be estimated by: 1) $X = (I-A)^{-1}Y$.

Most social, economic, and business objectives can be reached through more than one technology. Alternative technological methods of production can be assessed using the input-output techniques. Then the impacts of one method of reaching a goal can be compared with the impacts of alternative methods. For example, if the social goal were to increase grain production, this might be reached through increasing applications of fertilizer or, alternatively, through bringing marginal lands into production using perhaps, irrigation of dry lands or terracing or other soil conservation techniques on the marginal rough land. The sectoral economic impact of adopting one of these technologies or the other would be expected to be quite different.

The procedure used to make these comparisons is an expansion of equation 1 such that Y is an nxm matrix of investments needed to implement m different techniques. Then X becomes an nxm matrix of outputs required to implement each of these m

different technologies. This resulting gross output matrix, X, provides the basis for many of our subsequent impact analyses.

Employment

By defining appropriate coefficients of average employment requirement per unit of output, the researcher can estimate the effect upon employment by performing this matrix multiplication: $E = LX$

Where E is an nxm matrix of employment needs

L is an nxn diagonal matrix of coefficients of average employment per unit of output, and

X is an nxm matrix of gross outputs needed to supply the investment for implementing a new technology.

For example, if the coefficients of the L ·matrix were defined as the total civilian employment needs per unit of output, the employment needs vector, E, would be an estimate of the total employment commitment which the economy must make to implement the new technology. This procedure can be extended to more specialized analysis of employment needs.

Income

By using a similar procedure to that used to examine effects on employment of an investment project, the implications for income distribution also can be examined. 1/ In this instance we define the elements of our diagonal matrix to reflect some attribute of income per unit of output in the associated sector. In contrast to the employment impact analysis where both the level and distribution of employment were of interest, in income impact analysis, the distribution is of primary interest, because in the absence of leakage the total income generated will be the same as the initial exogenous investment.

Input-output analysis of the distribution of income resulting from an investment is a useful way to estimate some impacts of technology. When the attribute of income reflected in the diagonal matrix is total income (gross domestic product or value added), the resulting income distribution reflects the ultimate sectoral disposition of the income introduced into the economy by the investment needed for introducing the new technology. For example, 21 cents of the original dollar of investment in farm machinery is retained within the farm machinery manufacturing sector. (10) When several diagonal matrices are defined with such income components as wage and salary income, interest income, rental income, indirect business taxes, or profit-type income, it is possible to analyze the effect on income type or component as well as by sector.

By appropriately defining the coefficients of the diagonal matrix, which is subsequently postmultiplied by the matrix of gross outputs, a multitude of secondary economic impacts can be analyzed. Beyond the analysis of income and employment distribution, we can analyze the average consumption of any input per unit of output. For example, exhaustible reasources can be analyzed by defining coefficients of average consumption per unit of output. The contribution to air or water pollution can be analyzed by defining coefficients of average pollutant production per unit of output. 2/

The need for the healthy dose of professional judgment is now apparant. The I/O technique is indeed a powerful tool for mechanically producing vectors of total economic impacts. The limitations are in the analyst's ability to appropriately define the impacts to analyze, to appropriately develop the associated data, and to

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1/ Income distribution in this section refers mainly to intersectoral distribution, rather than personal or functional as stressed in economic literature.

2/ These estimates, however, are proxies for the actual resource usage or pollutant production. Alternative procedures should be employed for precise estimates of these effects.

properly implement the analysis.

The second generic application of input-output analysis to technology assessment is the analysis of modification of the cost structure of an economy or a sector of the economy by a technological innovation. While this type of analysis is rather appealing, the input-output cost coefficients are averages, and during the period required for existing production practices to be sufficiently replaced by newer techniques, it is unlikely that the cost structure in the rest of the economy will remain fixed. Thus, it is difficult to assess the value of research results such as Mann reported as part of his contribution to the ERS task force on tobacco harvesting mechanization. (7)

Mann defines eight tobacco production cost vectors associated with eight levels of technology. These eight column vectors are in turn introduced into a 20-sector direct requirement matrix from which a total requirements matrix, $(I-A)^{-1}$, is computed. The column sums of the total requirements matrix, the simple output multipliers, are examined. He concludes the simple output multipliers increase as the degree of mechanization reflected in a technology increase. Because a larger simple output multiplier indicates greater interdependence among sectors of an economy, Mann's conclusions are hardly surprising.

While the modification of one sector's cost structure to reflect a different technology may not yield particularly useful results, the discipline imposed by the construction of the modified input cost vector may provide some useful insights. As an illustration, all the new techniques in the tobacco harvesting mechanization study had direct requirement coefficients which were greater than or equal to associated coefficients in the base technology. These techniques all increased purchased inputs per dollar of output and, because there was no decrease in any category of intermediate inputs, none of the increased purchased inputs substituted for other purchased inputs. All the cost adjustment had to come from the substitution of purchased inputs for items in value added, that is, wages, interest, taxes, depreciation or net farm income.

A closer look at these components of value added provides further insights into the implicit substitution relationships. After mechanization, interest and depreciation costs would rise and because tax rates change slowly tax costs wouldn't change or would increase slightly due to the larger tax base. The adoption decisions are presumably made by the farm operator; thus it would be counter to economic logic to expect the net farm income share to be lower after adoption. Therefore with all nonlabor cost coefficients either increasing or remaining the same, a decline in labor costs must offset any other cost increase due to mechanization. The researchers in the tobacco mechanization study have described a pure labor substitution technology.

Constructing a vector of input requirement coefficients for a technology requires the researcher to address underlying input substitution relationships. Yet because underlying average production processes inherently change slowly, using these vectors in an I/O analysis to vary technological relationships while holding relative prices and demand conditions constant may be imposing such restrictive assumptions as to make the analysis unrealistic.

Some Macroeconomic Implications

We have portrayed the useful attributes of input-output analysis in disaggregating gross output by sector and specifying uses within those sectors. The aggregation of microeconomic sector analysis through input-output analysis provides a more complete macroeconomic perspective.

In conventional economics, certain levels of aggregate unemployment are matched with levels of inflation through the Phillips curve analysis. Yet, in any period of time, levels of output demanded, capacity utilization, unemployment, and factor availability differ among sectors. Furthermore, some sectors are better able to adjust their output level than others. Implementing a project which places additional demand on a presently tight sector often, in the short run, results in inflation rather than increased output. It has been argued that this partially explains the

inflation that followed the oil shortage, even under conditions of high unemployment. Using input-output models to identify this situation may allow the selection of projects which use technologies applicable to slack sectors and unemployed resources. The result could be the panacea of macroeconomic planning--higher levels of employment without price inflation, contradicting the levels of unemployment and price inflation dictated by the initial Phillips curve.

Determination of the economic impact of the investment needed to implement a technology can also be useful in meeting the objectives of economic stabilization. The business cycle can be smoothed out through the counter-cyclical timing of project implementation. For instance, construction sectors are subject to cyclical fluctuations. Projects which use the same factors as the construction sectors could be executed during recessionary periods. To some extent this has been attempted through the timing of expenditures from the highway trust fund.

A particular method of implementing a project can have an effect on the national distribution of income. Even though an expenditure may ostensibly have little to do with income distribution, the particular technology used to implement that project will cause distributional effects according to which factors of production it utilizes both directly and indirectly. The distributional impact of a particular method of project implementation can be examined in several ways. The income retained by each sector supplying the resources used in a technology can be measured as has been shown. Further, this income goes to wage and salary earners, nonwage and salary workers, or to profit earners who may also contribute primary inputs of the sector. Input-output techniques provide no clue as to the appropriate distribution of income. However, they can serve to highlight distributional patterns resulting from the provision of a technology and suggest specific technologies best suited to meet predetermined distributional goals.

Adjusting Nominal Costs to Reflect Social Costs

A commonly used tool of technology assessment is cost-benefit analysis. This entails the discounting of a stream of costs and benefits over the life of a project using one of several criteria. One area of controversy in cost-benefit analysis is determination of the best means of adjusting nominal costs to reflect social costs. When unemployed resources are brought into production as a result of the introduction of a particular technology, the social cost of this technology may be less than the nominal cost. One method of adjustment values resources at their social opportunity cost (the value of their next best use). Often public expenditure analysts adjust direct implementation costs to reflect social opportunity costs or other surrogate prices. Yet factors of production also have indirect uses which should reflect shadow pricing adjustments. To deal with this inadequacy, an input-output model was developed first by Robert Haveman and John Krutilla (6), and later by Haveman alone (5), which adjusts the cost-benefit criteria for conditions of unemployment. Haveman focuses on a specific factor of production, labor. However, the same analysis could be expanded to include other factors. Since labor is used in every sector, the linkages measured in an input-output model provide a more complete basis for adjustment of its cost.

To compute their model, Haveman and Krutilla first calculate the probability that idle labor will be brought into production in each sector resulting from the increase of demand for direct output required to implement a specific technology. They assume that the opportunity cost of idle labor is zero, although this is not necessary to the working of the model. By applying the probability of resources being priced at zero to the sectoral employment costs of the gross output vector, they adjust the total output for direct and indirect uses of labor. They compute the percentage difference between the cost of producing the total gross output without adjustment and the cost of producing it with shadow pricing of labor.

In the cost section of the cost benefit criteria, the initial cost of implementing a technology is amortized over the life of the project. By adjusting this amortized cost by the percentage adjustment in the price of the gross output,

both the direct and the indirect social savings generated by employing idle workers is taken into account. However, the amortized cost of initial implementation is only one part of the annual operating cost in the cost-benefit criteria, thus the adjustment is not complete but rather only a partial adjustment. Herein lies the weakness of Haveman and Krutilla's analysis. They implicitly assume that investments made under conditions of unemployment operate in a fully employed economy. They make no adjustment for the labor component of the other annual operating costs, thus overstating the social cost of a project when its annual operating costs are labor intensive. This oversight leads to the paradoxical and often incorrect result of favoring capital intensive projects as a result of adjusting the price of labor downward for conditions of unemployment.

Correction for this omission is not easy. It would be necessary to be able to know the rates of unemployment for all the sectors of the economy for the entire life of the project. Certainly for a long lived project this would be unrealistic. It seems prudent to conclude that the particular use of input-output analysis used by Haveman and Krutilla to adjust the cost benefit criteria for levels of unemployment, while theoretically interesting, has only very narrow applicability.

Summary and Conclusions

The study of the economic impacts of new technologies is a study of the economy of the future. Neither the technologies used nor the environmental conditions created by the investments can be easily changed once a technology is implemented. This places a high premium upon planning which could minimize mistakes and maximize the likelihood of successful introductions.

The long range context of such planning limits the usefulness of technology assessment by means of modifying the technical coefficients of selected sectors and by adjusting input costs to reflect social opportunity costs. The use of such techniques is further obfuscated by changes in relative prices, changes in levels of capacity utilization, and changes in other exogenous forces.

Input-output analysis offers a useful conceptual framework and means for analyzing investment strategies associated with introducing technologies. By appropriate definitions of coefficients of average usage, secondary effects on income, employment, or resource requirements can be estimated for the given level of investment required to implement a technology. However, input-output is not a panacea--it should be supplemented by both professional judgment and other techniques.

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USE OF LINEAR PARAMETRIC PROGRAMMING IN ASSESSING FEASIBILITY OF NEW TECHNOLOGY

by
Harold Taylor
Economic Research Service

Evaluations of new products derived from research require interaction by economists and physical scientists. Economists depend on physical scientists for technical data, while physical scientists depend on economists to utilize these data to determine the acceptability of new products to consumers and prices at which they would be competitive with similar products.

Interaction between economists and physical scientists requires an interdisciplinary approach. Interdisciplinary research is a continuous exploratory learning process in which many important decisions have to be made concerning not only the choices of research investigations but also the methodology utilized in evaluating and analyzing the results. Each professional discipline has conceptual boundaries within which the researchers nurture selective visions of reality and emphasize the inclusion and utilization of certain phenomena for project development and evaluation.

When the interdisciplinary approach is applied to a practical problem, researchers discover that an integrative theory is lacking. Ironically, the problems of interdisciplinary research expose the very shortcomings of an analytical technique which the interdisciplinary approach attempts to overcome. In order to overcome such problems, researchers involved in interdisciplinary projects must make choices so as to accommodate the different aspects of phenomena as they are seen from other disciplines and communicate these differences into a comprehensive methodology that interweaves each discipline's conceptual boundaries (1).

Computers in Research

Analysis of some research data can be simplified by using a computer, but it is first necessary to have a computer program and a data base. A computer program is a sequence of instructions that directs the computer to perform a specific series of operations, often to solve a specific problem. The data can be any representation of a fact or idea that is communicated or manipulated by some process. Computer computation is a great deal less expensive than manual processing; it has been estimated that one dollar of computer usage is equivalent to about one year of manual calculating costs.

Practically speaking, computers have become necessary in research. A new concept, time sharing, allows one to access computer programs and data banks at any location from any other location within seconds (2). All one needs are a terminal, a telephone, electricity, and a contract with a computer center for use of the facilities. Solutions can be obtained in minutes. This paper will show how one computer technique (linear and parametric programming) and a means of using this technique (time sharing) can be used to assess the impacts of new technology.

Linear Programming

Optimal use of limited resources is a basic economic issue. Through the use of linear programming (LP), the best solution to many resource allocation problems can be obtained. In many ways it is similar to the analytical techniques of comparative budgeting which were introduced into economics more than 90 years ago.

In budgeting, a plan is postulated for use of a set of resources, and the economic return from use of these resources is estimated. Another plan for use of these same resources is developed and an estimate of the economic return determined. The procedure is repeated until all feasible alternatives have been considered. Resources may be land, labor, capital, or requirements for a balanced feed ration. The key is that knowledge of the ways resources can best be combined is used.

Using LP, alternative budgets are not developed. Instead, data are manipulated until the most feasible plan has been obtained. In more technical terms, LP is one of many mathematical tools which can use alternative procedures, subject to limitations or constraints. Basically, LP is a technique that determines a set of non-negative variables that satisfies a system of linear equations in such a way that a predetermined objective function is optimized, subject to selected constraints. To facilitate the solution, equations representing inequalities are converted to equalities by adding slack and artificial variables. Under these conditions there generally are more unknowns than there are equations; and many possible mathematical solutions exist.

The LP model can be expressed as either maximizing or minimizing an objective function, subject to the following, where

(1) $$\sum_{j=1}^{n} a_{ij}x_j \begin{smallmatrix}\leq\\=\\>\end{smallmatrix} y_i \text{ where } i=1,\ldots,n,$$

and a_{ij} represents the input-output coefficient; x_j, the unknown level of output; and y_i the level of known constraints. Such a linear equation can more easily be expressed in matrix notation. A matrix is an array of numbers or a table of numbers. For the sake of convenience, capital letters will be used to signify matrices, and lower case letters to signify elements in the matrices. For example, the above expression can be represented in matrix farm by first representing the set of linear equations of which it is composed:

(2) $$\begin{bmatrix} a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots a_{1n}x_n \leq y_1 \\ a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots a_{2n}x_n \geq y_2 \\ a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \ldots a_{3n}x_n \leq y_3 \\ \vdots \\ a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots a_{mn}x_n \geq y_m \end{bmatrix}$$

The equations above, which are inequalities, can be changed to equalities by adding slack variables to the left-hand side,

$$
(3) \quad \begin{bmatrix}
a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \dots + a_{1n}x_n + b_1z_1 & & & & = y_1 \\
a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \dots + a_{2n}x_n & - b_2z_2 & & & = y_2 \\
a_{31}x_1 + a_{32}x_2 + a_{33}x_3 + \dots + a_{3n}x_n & & + b_3z_3 & & = y_3 \\
\vdots & & & & \vdots \\
a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \dots + a_{mn}x_n & & & - b_mz_m & = y_m
\end{bmatrix}
$$

where b_i are coefficients of the slack variables z_i, all having a value of 1.

Equation (3) can now be expressed in matrix notation, as follows:

$$(4) \quad A X + B Z = Y$$

Equation 4 combined with the objective function, represents a typical linear programming problem. The problem is to find the values of the x_j's that satisfy Equation (4) and either maximize or minimize the objective function.

The simplex or revised simplex algorithm is a practical and efficient means of obtaining a solution. The simplex method is based on the assumption that if the constraint equations are linearly independent, there corresponds a set of columns or variables which are also linearly independent. Therefore, any constraint can be expressed in terms of these columns. The simplex method exchanges one column and row until a basic feasible solution is obtained--a solution which satisfies the equations and constraints. The simplex method then proceeds until the objective function is optimized.

The solution of these constraints for the level of variables needed for an optimum solution requires the inverse of the A matrix (A^{-1}). This has led to development of the revised simplex method. The main difference between the two is that in the simplex method all elements in the model were transformed, while the revised method only transforms the elements of the A matrix.

Linear Parametric Programming

Linear parametric programming (LPP) is a refinement of LP which adds a degree of flexibility to an otherwise rigid structure. It enables one to analyze at different levels at least one coefficient. The coefficient can be an element from either the A matrix or the Y matrix, or from the objective function. For example, if price is the coefficient, this technique can determine the total demand curve of a given coefficient.

With LPP, as with any analytical technique, the answer can never be more important than the question. What's more, the answer can be no more accurate than the measurements used in the analysis. Therefore, LPP may be a new analytical vehicle, but it isn't any better than the assumptions and data used.

An Example of Technology Assessment Using LPP Techniques

Effluent from leather tanning and finishing factories operations creates serious environmental problems. Cooper (3) determined that a tannery processing an average of 2,500 hides per day would discharge about 8,500 pounds of BOD 1/ daily. This discharge is equilvalent to a domestic population daily BOD discharge of approximately 71,500 people.

1/ BOD can be defined as a measure of the biodegradable organic compounds in waste streams.

EPA established guidelines to control effluent discharged into navigable waterways in the United States from tanneries (4). Already, some tanneries have closed because they could not meet local pollution standards.

Tanneries need methods for turning large quantities of proteinaceous solid wastes into marketable products. Tannery unhairing effluents are complex mixtures of partially disintegrated hair, fat, particles of hide, lime, degraded solubilized proteins, sodium sulfide, and possibly some emulsified fat and sulfur (5). At the ARS Eastern Regional Research Center, scientists have developed such products from tannery unhairing effluent. Two are in the initial evaluation stage: (1) a 91 percent protein material precipitated from tannery unhairing effluents (91 Protein), and (2) acclimated activated sludge from biological treatment of tannery unhairing effluents (AA Sludge 90). Both were analyzed to determine their elemental and amino acid compositions. They were both found to be high in protein nitrogen and free of potentially toxic levels of heavy metals. Coefficients were obtained from the scientists so that each of these products could be economically treated as a potential feed ingredient in least cost poultry rations.

Products 91 Protein and AA Sludge 90 were analyzed for use in poultry feeds through the use of a satellite computer terminal using LPP price sensitivity techniques and nutritional data banks for poultry and swine supplied by Maddy Associates, Inc., through the services of Com-Share Computer Utility Co. To these data banks, additional vectors of coefficients were added for each of the products. A separate computer evaluation was run for each of the products. Prices were obtained from either "Feedstuffs," "Chemical Marketing Reporter," or Nutrition Service Association, Belleville, Illinois 2/. To help determine the economic utility of the products as poultry feed, a layer phase II average summer ration was selected from the egg production program data bank (EPP), and a layer ration and a broiler finisher ration were selected from the poultry and swine program data bank (PSP).

In each case, a least cost computer solution was first obtained without use of the new product. The potential value of each product to the selected ration was then determined by LPP cost ranging to obtain product demand curves, figures 1 and 2. Prices, ration requirements, and bounds 2/ on ingredients were held constant while the price of the new product was allowed to vary from $1,000 to -$5 per hundredweight. Points of substitution were obtained as the price of the new ingredient decreased and nutritional factors in the new product were substituted for nutritional factors from some other source. At each point of substitution, a complete poultry ration could be obtained which would conform with the restrictions, ration requirements, and bounds incorporated in the model. Changes in any of the coefficients, prices, constraints, and bounds would possibly result in different points of substitution and demand curves.

As can be seen from figures 1 and 2 on the following pages, these products could economically compete with other ingredients in poultry diets provided that production costs do not exceed acceptable prices and that feeding tests confirm these analyses. Most feasible use of these products would possibly include 2 percent or less of 91 Protein in all rations, and 4 percent or less of AA Sludge 90 in PSP layer ration, assuming these products would cost between $8 and $16 per hundredweight.

2/ Generally, prices for grains were quoted at Chicago from "Feedstuffs," August 25, 1975. Prices for other ingredients as well as chemicals were either obtained from "Feedstuffs," "Chemical Marketing Reporter," or Nutrition Service Association for approximately the same time period and are considered to be average prices quoted from various locations in the United States.

3/ In addition to the restrictions, constraints, and nutrient requirements of the rations, upper and lower bounds were placed on many ingredients which level of usage in a ration, if used, would be restricted. These bounds restricted the maximum amount of the new products used in the various diets of each ration even when the costs of the new products were assumed to be zero or at -$5 as illustrated in figures 1 and 2.

Conclusions

LPP is only one analytical tool used in technology assessment. The assumption of linearity may be questioned; however, in many projects it is safer than other mathematical relations. Research is required to determine values for coefficients with an acceptable degree of accuracy. Most problems can be minimized by building proper restrictions into the matrix. Remember, results can never be more important than the original question, no matter how refined the analytical tools used. Also, this method only measures direct effects of new technology.

The examples used here emphasize the importance of integrating the methods of the scientific and the economic disciplines into a comprehensive approach. ARS scientists had conducted many scientific tests before the economic analyses were made. Still, other analytical tools may have to be used in the total assessment of new technology.

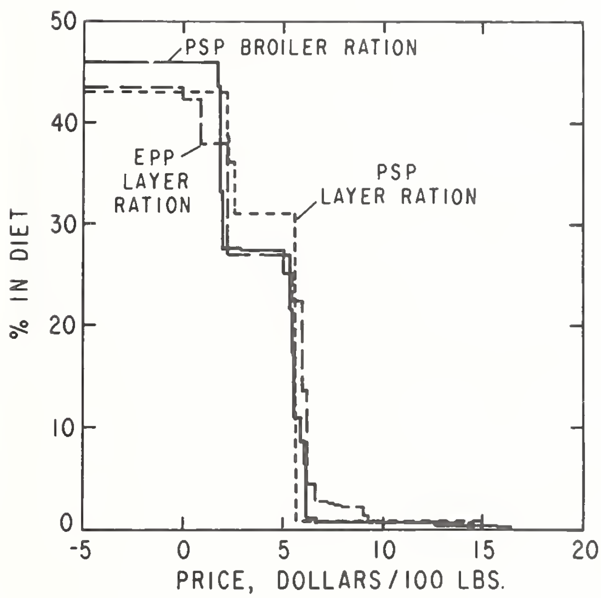

Figure 1. 91 Protein

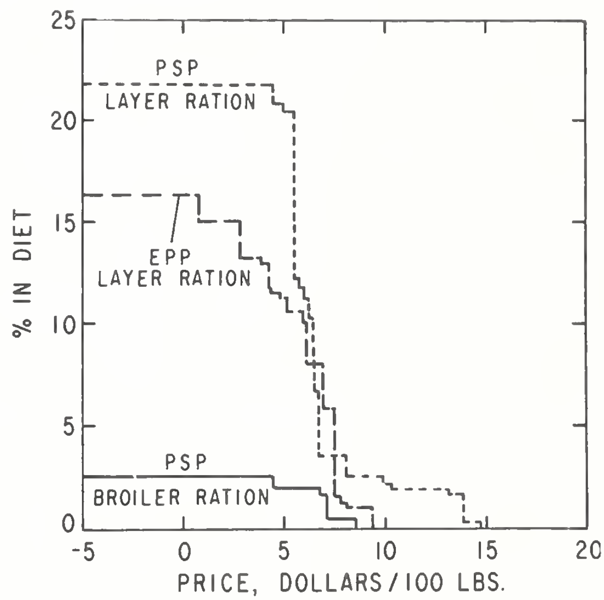

Figure 2. AA Sludge 90

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FORECASTING THE RATE OF ADOPTION OF TECHNOLOGY

by
James E. Kirkley
Economic Research Service

Two methods are widely used to forecast the rate and extent of adoption of technology. They are a simple trend extrapolation and a "goodness of fit" of the S-shaped logistic function. Both methods may provide useful estimates of future adoption patterns, based on observed prior rates of adoption. However, these methods have some technical limitations, of which analysts should be aware. They relate to inadequate decisionmaking information, inadequate information for long-term forecasting, poor choice of model (the S-shaped logistic function), and the omission of a disturbance term from currently used logistic models.

The purpose of this paper is to discuss the rationale underlying the limitations of the currently used methods for forecasting the rate and extent of adoption of technology. Some suggestions are made on how to cope with these limitations.

Inadequacy of Information for Decisionmaking and Long-Term Forecasting

There are two major reasons why the currently-used methods fail to provide adequate decisionmaking information: Neither requires identification and measurement of the impacts of policy variables, or shows how to alter the policy variables in relation to desired impacts; and the dynamic aspects of the rate of adoption tend to invalidate long-term projections.

At least two pieces of information are needed to formulate plans and policies to deal with the impacts of new or existing technology: Knowledge about the policy variables that policymakers or planners can influence, and information about how these variables affect the rate of adoption.

Neither trend extrapolation nor a goodness of fit of the logistic function provide this information. 1/ This appears to be the result of two things: It is not certain which variables affect the rate of adoption, and there are insufficient data to test if certain hypothesized variables influence the rate of adoption.

The rate of adoption is a dynamic process because the influences that affect the rate of adoption are subject to several changes over time. Examples of these changes are as follows: (1) complementary resources can become more efficient, thereby changing the adoption rate of new technology, (2) better substitutes can be developed, (3) prices of either complementary resources or substitutes can change, (4) laws that affect the rate of adoption can change, (5) the demand for the item which the new technology helps to produce can change. There are many other dynamic elements that could also affect the rate of adoption, but these are enough to illustrate that the rate of adoption is a dynamic process.

Since the rate of adoption is a dynamic process, long-run forecasts of the rate of adoption are subject to errors of estimation that increase with time. Short-run projections are subject to fewer errors. Therefore, they have the potential to provide relatively better information. Although short-run forecasts are more likely to be

1/ This is not completely true because Edwin Mansfield (10) determined that at least three variables affect the rate of adoption. However, he estimated a combined effect of the variables on the rate of adoption rather than their specific effects.

correct than are long-run predictions, they still may fail to provide policymakers and planners with enough information about new technology to adequately formulate plans and policies.

Both of the limitations discussed in this section are serious. However, they can be partially alleviated by pursuing four objectives: (1) attempt to account for the dynamic elements of the rate of adoption by introducing a disturbance term, (2) if long-range forecasting is necessary, try to restrict analysis to the general direction of change rather than interpret the absolute forecasts of the rate of change, (3) identify the policy variables that policymakers and planners can influence, and (4) estimate the impact of identified policy variables upon the rate of adoption.

Problems of Forecasting with S-Shaped Growth Curves

In addition to those problems discussed in the preceding section, there are problems associated with the current practices of using S-shaped growth curves to estimate the rate of adoption.

Choice of the S-shaped Function

The most widely chosen S-shaped curve to forecast the rate of adoption is the logistic curve. 2/ That is because it is assumed that the rate of adoption follows an S-shaped curve over time (see Figure 1). However, there currently is some debate as to the validity of this assumption.

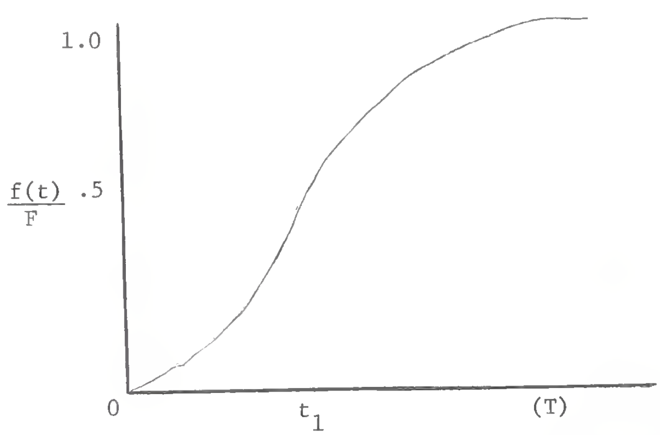

Figure 1. The Rate of Adoption of Technology: $f(t)/F$ = rate of adoption, $T = t - t_1$ (t = the year when a firm adopts an innovation and t_1 = the year of the initial adoption)

2/ For further explanation of this, see (6).

The arguments against using the S-shaped logistic curve are:

(1) Estimates so obtained are little more than a restatement of facts(11, p.11);
(2) other distributions, such as the Cauchy or Normal, can be fitted to the same data and give comparable or better fits (4, p. 52);
(3) the S-shaped curve does not allow for technological shocks or shifts in the system.(11).

All these arguments appear to be valid.

A Deterministic Logistic Model

There also is a problem in that many of the logistic models consider only the deterministic part. That is, they do not allow for unexplained variations in the rate of adoption. 2/ Therefore, they are neglecting an important dynamic element--the error or disturbance term. 3/

The error term should be included because it specifies that the functional relationship is not exact, but approximate. It is also necessary because it allows for random unexplained variations in the rate of adoption. Furthermore, most of the logistic models claim to be regression models, and the error term is necessary in a regression model.

If the error term is included, the forecasting equation or conditional mean will be different from the one currently used to forecast the rate of adoption. 4/ As a result, the forecasts of the rate of adoption will be different. In order to demonstrate this, it is necessary to first discuss the logistic model normally used to forecast the rate of adoption.

The Model

The logistic model currently used to forecast the rate of adoption is: 5/

$$f(t)/F = (1 + e^{-(a + bT)})^{-1} \qquad (1)$$

where $f(t)$ is the number of firms that adopt an innovation at time t;

F is the maximum number of firms or units upon which the results are based;

and T is the number of years between when the innovation was first introduced in the industry, and when a particular firm adopted the innovation.

2/ Mansfield in (10) recognized that there were unexplained variations; however, he considered only the deterministic part.

3/ For a more detailed discussion of the dynamics and the error term, see Chou, Gregory C., Analysis and Control of Dynamic Economic Systems, John Wiley and Sons, Chapter 3, N.Y., 1975.

4/ The conditional mean is the regression curve. It is considered to be the forecasting equation or policy response equation.

5/ This is the same notation used by Blackman (2). However, I have used "T" to distinguish it from the subscripted U_t.

In order to use equation (1) to predict the rate of adoption, $f(t)/F$, it is necessary to estimate the parameters, a and b, from the log-linear form of Eq. (1)

$$\frac{\ln f(t)}{F - f(t)} = a + bT \qquad (2)$$

by applying ordinary least squares.

Once a and b are estimated, the rate of adoption can be forecast:

$$\widehat{f(t)/F} = (1 + e^{-(\hat{a} + \hat{b}T)})^{-1} \qquad (3)$$

where $\widehat{f(t)/F}$, $\hat{a}$, and $\hat{b}$ represent estimates. Forecasts from equation (3) would only be relevant for the deterministic case. They would not allow for stochastic changes. These changes can be partially accounted for by introducing a stochastic term--the error term or disturbance.

As already discussed, the error term is necessary to account for the unexplained variations in $f(t)/F$. It seems plausible that the time variable (T) cannot explain the entire rate of adoption. 6/ Furthermore, addition of an error term introduces a dynamic element to the rate of adoption.

There are two possible results of omitting the error term from equation (1): (1) the conditional mean or forecasting equation fails to allow for any random disturbances, or (2) the estimates of a and b are incorrect. 7/ However, these will depend upon how the error term is included in equation (1).

The error term could be included in several ways--additive, multiplicative, exponentially, logarithmically, and so forth. Due to the log-linear form of the logistic model, the most obvious way would be to include the error term as follows:

$$((f(t)/F)|T) = (1 + \exp^{-(a + bT + u_t)})^{-1} \qquad (4)$$

If the error term was included in the form of Equation (4), the log-linear equation used to estimate a and b would be as follows:

$$\frac{\ln f(t)}{(F - f(t))} = a + bT + u_t \qquad (5)$$

Estimation of a and b would be accomplished by using ordinary least squares and the assumptions normally made about the disturbance term (the mean of u_t is equal to 0, the variance of u_t is equal to constant σu^2, and the covariance between $u_t u_s$ is equal to 0 where t does not equal s).

Estimates of a and b obtained from equation (5) would be the same as those obtained from equation (2). They would both be consistent, but forecasts of the rate of adoption would be different. This is because addition of the error term results in a different conditional mean.

6/ This is further supported by the fact that it has been determined that the time parameter (b) is really the combined effect of several variables including an error term. For further explanation, see Mansfield (10).

7/ An example of this would be to consider the following model:

$$f(t)/F = (1 + e^{-(a + bT)})^{-1} + U_t.$$

The desirable conditional mean would be the same with the expected value of U_t equal to zero. However, the log-linear form would have log U_t, and obviously this would cause an estimation problem because if the expected value of log $U_t = 0$, then $U_t = 1$, a constant. Thus, the conditional mean would be $f(t)/F = (1 + e^{-at + bT})^{-1} + 1$.

The conditional mean is found by taking the expected value of $((f(f)/F)|T)$. Derivation of the conditional mean is as follows:

$$E((f(T)/F)|T) = \int_{\infty}^{\infty} (f(t)/F)\ f(u_t)\ du_t \qquad (6)$$

where $f(u_t)$ is the probability distribution of u_t. However, this requires an assumption about the distribution of u_t. The easiest assumption to make is that u_t has a normal distribution with a mean of 0 and a variance of σu^2. The conditional mean can now be found by use of the following integral:

$$E((f(t)/F)|T) = \frac{1}{\sqrt{2\pi}\ \sigma u} \int_{\infty}^{\infty} \exp\ (-u_t^{2}/2)\ \frac{du_t}{(1 + \exp^{-(a+bT+u_t)})} \qquad (7)$$

The conditional mean also can be found by using a recently developed approximating technique. 8/

Once the conditional mean of equation (4) is derived, forecasts of the rate of adoption can be made. These forecasts should be preferred over those made from equation (1) because they allow for a stochastic element (u_t)

Although forecasts made from the conditional mean of Equation (4) are statistically more desirable than those made from equation (1), these forecasts still do not provide adequate information about the policy variables. It is necessary to identify the policy variables and their effects on the adoption rate.

Summary and Conclusions

This paper has stressed some of the major limitations of forecasting the rate of adoption by using either trend extrapolation or log models: Estimates of the long run forecasts of the rate of adoption may be subject to large errors because of intervening dynamic variables; inadequate information for policy officials may result because of lack of inclusion of policy variables in the explanation of adoption rates; choice of the S-shaped logistic function may be incorrect; and, the logistic models currently used to forecast the adoption rate consider only the deterministic part, and thereby fail to adequately allow for dynamic changes.

These limitations could be partially alleviated by pursuing four objectives: (1) If long-range forecasts are necessary, analysis should be restricted to the general direction of change rather than the absolute quantity of change; (2) identify and test the significance of variables as determinants of the adoption rate; (3) consider and test alternative functions for depicting the rate of adoption; and (4) determine the conditional mean of the logistic model with an error term included.

Of these four objectives, the second and third appear to offer the greatest potential for improving the information process. This is because realization of these objectives should result in a formal theory on the rate of adoption--a theory which currently is almost nonexistent.

If the major purpose of policymaking or planning is to either minimize the detrimental impacts or to promote the beneficial aspects of new technology, policymakers and planners need to know more about the rate of adoption and what it might be in the future than current methods provide. They should know what the relevant policy variables are, and how these variables influence the adoption of technology. A way to provide this information is to develop a formal theory on the rate of adoption, theory that considers the variables as a dynamic system.

8/ For further details of this technique, see (8).

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SOME PROCESSES IN EVALUATING IMPROVED WORLD CROP INFORMATION (LACIE)

by
Frank H. Osterhoudt
USDA LACIE Project Office
Foreign Agricultural Service

The Large Area Crop Inventory Experiment (LACIE) is a major effort to assess the utility of technological advance to satisfy user needs for better agricultural information. Most of the technology and procedures which LACIE is now testing have been tried elsewhere. The objective of LACIE is to determine whether these technologies and procedures can be assembled and developed into an operational crop estimating system which can complement the international crop information system of the U.S. Department of Agriculture (USDA).

This paper will provide a brief background for LACIE, described the overall economic evaluation process, and then concentrate on one activity within that economic evaluation--a study titled "Use and Value to the USDA of Crop Information", or simply "Information User."

Data for this study will be acquired primarily by indepth interviews of USDA decisionmakers to learn how they use crop information and what value they place on improved information. Similar processes will be required to ascertain the value of improved crop information to other users.

LACIE Background

Current and reliable crop information is considered essential in many decisions. Decisionmakers using crop information are located in both the private and governmental sectors. To meet this need, USDA has the prime responsibility for developing and distributing crop information. The Statistical Reporting Service (SRS) collects and reports U.S. crop production information. The Foreign Agricultural Service (FAS) is responsible for collection and distribution of foreign crop information.

FAS is often faced with special problems in developing required crop data. They include incomplete or missing data, delays in data availability, possible biases and inconsistencies in available data, and inadequate baselines for comparisons. The LACIE shows potential for overcoming or alleviating some of these problems which are inherent in a foreign data collection and analysis program.

LACIE is a cooperative venture between USDA, the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA). Its objective is to develop and test a system which can estimate world wheat production. This will be done over 3 crop years. Accuracy goals for the experiment are, at the country level, 90 percent, 9 years out of 10. (Accuracy and timeliness requirements for an operational USDA crop forecasting system have been tentatively defined in the USDA's user requirements document, and will be further refined and finalized during the course of LACIE.) Improvements of USDA's present foreign crop forecasting systems in terms of timeliness, accuracy, and objectivity are anticipated. It should be noted that LACIE is not expected to improve the accuracy of U.S. crop reports.

LACIE is designed to meet FAS needs in areas where ground information is not readily available, so the LACIE system must be tested where ground information is available for purposes of validation and calibration. Therefore, the U.S. Great Plains has been chosen as one of the test regions.

Agency Responsibilities and LACIE Phasing

NASA's primary responsibilities associated with LACIE include the acquisition and processing of satellite data, locating the specific sample segments (registration), and the identification and measurement of wheat in those segments. The technology began with the Earth Resources and Technology Satellite, now called Landsat. The original satellite, Landsat 1, is still orbiting but provides only backup data. Landsat 2 is the current operational satellite. Landsat 3 will be launched in 1977 and is expected remain operational until late 1980. Decisions on Landsat follow-on systems are pending. The Landsats are circling the earth at an altitude of about 575 miles. They have been placed in polar orbit which permits the acquisition of data from the same place on the earth's surface at the same time of day every 18 days. The images are made by a multispectral scanner (MSS), an optical-electrical system rather than all-optical. Advantages of the MSS are that it covers a wider spectrum of radiated energy than optical or sight, and is adaptable to computer handling without conversion from photographic film to digital form. A disadvantage is that you can't "see" as fine detail as you can with other methods.

NOAA's primary responsibility is yield estimation. NOAA has developed models to incorporate historic yield trend with current weather factors to produce yield estimation. It also helps by developing crop calendars which relate the various average wheat growth stages to calendar dates. These crop calendars are used as an aid for NASA in separating wheat from nonwheat, and in assessing the effects of weather on wheat production.

USDA has several major responsibilities associated with LACIE. Since all of the wheat estimates are made on the basis of statistical samples, USDA is evaluating and developing alternative sampling techniques. Production estimates, the actual combination of NASA wheat area measurements and NOAA yield estimates, are made under USDA leadership. USDA is responsible for defining USDA user requirements for crop acreage, yield, and production information. USDA is also responsible for evaluating the cost effectiveness of a LACIE-type crop forecasting system.

The LACIE program has three phases. Each phase covers a global crop year, which begins with the first planting of Northern Hemisphere winter wheat, and ends with the final spring wheat harvest in the Southern Hemisphere. Crop years have no ties to budget cycles or other calendars. Phase 1, a startup period to get things in place and to estimate wheat acreage in the Great Plains, has just been completed. Phase 2 is now under way, and Phase 3 will test more completely LACIE technology and performance.

The Overall Economic Evaluation Process

There is a long list of potential audiences and beneficiaries of information produced by a LACIE-type system. These may be USDA, other executive departments, the Congress, independent agencies, farmers, agribusinessmen, and consumers.

When estimating benefits, one may attempt to look at the whole picture, as some recent major studies have done.

Another approach to estimating benefits might be called partial analysis. We have chosen this approach--to look at the use and value of crop information to selected users. As with the LACIE project, we are limiting ourselves to wheat information.

Costs will be considered for a LACIE-type operational system. LACIE is an experiment and is not designed to be cost-effective. The roughly 400 people associated with LACIE at the Johnson Space Center (JSC) could be replaced by perhaps 50 to 60 in an operational system. The huge computers used for putting a man on the moon can be replaced by efficient minicomputer systems. The design of such an operational system has been started by a USDA-led group at JSC.

When considering the cost-effectiveness of LACIE, alternatives for comparison would include increasing the capabilities of current collection and estimating systems, and utilizing systems which are classified for national security reasons. These alternatives

have received only preliminary consideration and will be pursued if senior USDA management expresses an interest.

1976 Economic Evaluation Report

The 1976 OACIE Economic Evaluation Report, due in September 1976, will consist of several parts. The first, "Information Use," is an analysis of data obtained in in-depth interviews with USDA decisionmakers.

A second part consists of (ERS) modeling efforts to support information benefits analysis of LACIE or "modeling benefits" for short. This effort will use the ERS POLYSIM model to estimate the effects of improved LACIE wheat information on commodity price forecasting, farm income, target price and loan levels, Government costs under alternative programs and decisions, and consumer food decisions.

A third part will be the cost of a LACIE-type operational system. Only the most preliminary estimates will be available for the 1976 report.

1977 and 1978 Economic Evaluation Reports

For the 1977 and 1978 reports, several evaluation processes are planned:

- The evaluation of the utility of LACIE information to USDA will be refined, including an evaluation of how it could supplement existing systems.
- The utility of LACIE wheat information to farmers, the agribusiness community, and agricultural organizations will be investigated indepth.
- The utility of LACIE information to other Government users and to selected private sector beneficiaries will be evaluated.
- The costs of an operational LACIE will be estimated and related to the benefits of LACIE.
- Preliminary comparisons with alternative crop estimating procedures will be made.
- Tentative extensions of LACIE results will be made to crops other than wheat, and these efforts will be coordinated with economic evaluation efforts of the USDA Remote Sensing User Requirements Task Force.

Use and Value to the USDA of Crop Information

The "Information Use" study is one of the two major economic evaluations done in the spring of 1976. Our purpose is to evaluate how present domestic crop information and improved foreign crop information affect USDA. The areas which may be affected include policy decisions, program actions, the ability to analyze and respond to the impacts of potential changes in policy, and the improvement of forecasts having economic consequences.

Joint LACIE/SRS Effort

SRS participates in our study, and both LACIE and SRS have current responsibilities for assessing the use and value of wheat information. We must know the potential usefulness to the USDA of the incremental information expected to be provided about foreign wheat production.

SRS needs to assess its own utility and usefulness to the various USDA agencies in providing domestic wheat information.

Agricultural and Information Experts to Participate

In "Information Use" we are joining two groups of experts: We have contracted for special expertise in collection and analysis of the use and value of information. Additionally, USDA user agencies are providing us with specialists in agriculture, who understand both the crop information and analytical processes, and the uses made of the information.

The experts in valuing information will use accepted analytic techniques and interviews with various USDA decisionmakers, agency and program managers, information analysts, and other data users to evaluate how modifications in the present domestic and foreign crop production estimation systems could be used by USDA. The interviews will probe how crop information is used and its value to respondents, how modified information could be used, and the effects of modification of crop information on USDA policies and programs on ability to analyze and respond to the potential impact of policy changes, and the capability of improving economic forecasts. Those interviewed will be asked about the direction and general magnitude of the effect on such variables as program costs, farm income, and consumer prices.

Specialists in the fields of commodity analysis, international trade, foreign policy, and domestic policy will provide technical agricultural information and help design the interviews and develop scenarios. Needed agricultural information will include uses, sources, and characteristics of crop information. The agricultural specialists will suggest questions to ask. They will suggest alternatives which might be used to guide the interviews. Later, they will help evaluate the study itself.

Then, we might present the results of the interviews to a panel of USDA experts for evaluation of: Types or groups of persons which would be affected by modification of crop information as may have been specified in the interviews: numbers of persons in USDA and the number of firms or groups in the private sector who would be affected: and nature of the impacts on these groups--including an estimate of the dollar benefits or costs to each of these groups. The interview study (and, if carried out, the panel evaluation) will form a background for one or two principal chapters to the 1976 LACIE Economic Evaluation Report.

STRUCTURING A TECHNOLOGY ASSESSMENT OF FABRICATED FOODS: A Workshop Exercise

by
Ray W. Nightingale, Larry G. Traub and Herbert E. Robinson
Economic Research Service

This paper presents results of an exercise in the application of interpretive structural modeling (ISM) to the problem statement phase of technology assessment. The attributes of ISM as a tool for technology assessment are presented, and the advantages and limitations demonstrated by this structuring exercise are discussed.

Structuring a Technology Assessment

The tool employed to aid a particular inquiry should as nearly as possible meet specific needs. To develop proper tools for technology assessment, knowledge about what tools are needed is required. Considerable insight can be gained in this by reviewing Coates' elaboration of the phases of a technology assessment: 1/

1. A statement of the problem to be considered, usually a broader restatement or recasting of the problem after analysis is underway;
2. Definition of the system (technology), and specific alternatives which could accomplish the same objectives (micro-alternatives);
3. Identification of potential impacts - a creative enterprise requiring imagination and speculation;
4. Evaluation of potential impacts - a mixed effort of firm-handed analysis and informal judgment necessarily conducted on "semi-solid" footing;
5. Definition of the relevant decisionmaking apparatus - a step which is often neglected;
6. Laying out options for the decisionmaker - since traditional categories may now be inadequate, new inventions and imaginative development of options are usually appropriate and often needed;
7. Identification of parties of interest; potential "winners" and "losers" including both overt and latent interests;
8. Definition of "macro-alternatives" - not alternative technologies as considered in 2, but broader systematic alternatives such as energy conservation or solar energy generation rather than the Alaskan Pipeline (this step provides a standard for challenging conclusions drawn from 1 through 7);
9. Identification of exogenous variables - events which may disturb the system (that is, natural catastrophes, wars, embargoes, depressions, changing birth rates, and so forth.);
10. Conclusions and possibly recommendations.

The evident prominence of thinking as a process in technology assessment is not confined to problem formulation (phase 1) but is prevalent throughout the assessment activity. Specification of micro-alternatives (phase 2) necessitates exploring the perspectives of closely related disciplines, while specification of macro-alternatives (phase 8) requires an exchange of views among more disparate groups. Identification of impact areas (phase 3) and parties of interest (phase 7) are activities requiring great insight and imaginative thinking.

The system within which a technology is to be introduced is often highly complex. In addressing the consequent problem situation, investigators confront the risk of

overlooking either an element in the system or a relationship among elements. This danger is caused by the limited ability of any science to comprehend fully the implications of changing technology and by the scientist's tendency to elevate in importance those facets of the problem which his own science customarily addresses. Thus, whereas the disciplinary scientist may rely to a considerable extent on theory as a basis for modeling, the technology assessor may rely heavily on views and observations of diverse experts.

In the absence of a comprehensive theoretical base, and the associated analytical tools, much of a TA exercise is devoted to establishing new frames of references around which to build dialogue and analysis. This is essentially an interdisciplinary exercise.

In her portrayal of the role of models in technology assessment, Jean Johnson classifies models as thinking, testing, or tasking tools. 2/ These correspond in technology assessment to (1) the establishment of relationships in a broad problem specification, (2) the examination of social and economic consequences of alternative technologies, and (3) the detailed analysis on which economic and technical feasibility decisions can be based. Johnson's "thinking" models relate primarily to the first three of Coates' phases of assessment. These thinking models are generally classified by scientific methodologists as structuring models. 3/ The distinguishing feature of structuring models is that they make no a priori assumptions regarding identity of system variables or relationships. The function of these models is to pragmatically identify the prime variables in a system, thus reducing its complexity. While structuring is an essential first step in the study of complex systems, it must be followed by analysis which addresses the intensity of relationships. 4/

Interpretative Structural Modeling 5/

Interpretive structural modeling (ISM) is a thinking, or structuring, tool. It aids in bringing the knowledge and judgments of numerous experts to bear upon a particular problem; assisting in the systematic exploration of all possible binary relationships among a set of problem elements; and, portraying the identified relationships via a diagraph (directed graph). There is a mathematical correspondence between diagraphs and matrices. In ISM the problem to be structured is expressed as a binary matrix indexed by ordered "problem" elements and having entries defining ordered pairs of those elements. A binary relation is expressed as a partition of the matrix into blocks R and $\bar{R}$ of entries 1 and 0, designating existence or nonexistence of a specified relation among paired elements. If only part of R is known (R_a), then a partial description of the relation exists. For any partial description there exists a reachability matrix from which $R-R_a$ is generated, and a diagraph is constructed. ISM thus utilizes the mathematical correspondence between diagraphs and matrices to employ automatic data processing in the relationship identification process. 6/

Basically, ISM explores the elements constituting an issue. The issue is analogous to an area of inquiry in conventional research. The elements are the facets of a major research problem. These facets have an impact on consumers, producers, food processors and distributors, various public programs, transportation, etc., and bring many previously nonexistent problems of various magnitude to the forefront.

An additional but critically important component of the structuring exercise is the relational statement: a single verb clause that permits participants to make a common comparison of all pair-wise combinations of elements in the element set. The specification of the relationship (the transitive verb employed) is determined by the problem context and the objectives of the inquiry.

The affirmation or denial of the existence of the specified relation between pairs of problem elements is done via dialogue and balloting, usually by a nominal interdisciplinary group of experts. This activity allows for the presentation of opposing viewpoints on the interpretation of the relational clause and on the meaning of each stated problem element. The final product of an exercise, the diagraph, portrays the structure of the problem to be assessed, i.e., the result of an interactive and interdisciplinary treatment of the issue.

ISM EXERCISE

The Issue

The technology assessment issue chosen to be structured (that is, the problem situation explored) was the emergence of substitutes for food products of animal origin. 7/ Many substitutes have been developed for certain dairy, red meat, egg, and poultry products. Margarine, whipped toppings, coffee whiteners, whey-soy blend and imitation milk are some dairy substitutes. Textured soy flour and concentrates have been used as meat extenders, and soy and other vegetable proteins have been fabricated into analogs that resemble ham, beef, and chicken. Substitutes have been developed that will replace eggs as ingredients in baked goods and other manufactured products. In another generation of egg products, vegetable oil is substituted for yolk and is intended as a substitute for eggs for direct consumption.

Modeling Relationships

This set of technological innovations is anticipated to have a wide range of impacts, solving or creating problems for a multiplicity of parties of interest. The unanticipated adverse consequences of new technology concern us because they may render institutions obsolete, create health problems, and so forth. Alternatively, unanticipated beneficial consequences might be commercial and social windfalls which could critically influence the decision to proceed with the development of a technology. With an issue as potentially complex as the one addressed, the perspective and scope of the exercise is thus strongly influenced by selection of the relational clause, the foundation of the structuring exercise.

To demonstrate the capability of this method, to define problems, and to constrain the time requirements of the exercise, we chose the relation "does element A aggravate element B" where A and B are any of the problem elements identified by the methods described in the following discussion. As technology assessments comprehensively address impacts, practical ISM exercises should employ relational statements focusing on both problems and benefits.

Identifying Elements of the Problem

Ideally, the most professionally capable people having the greatest familiarity with the issue addressed would be assembled for the structuring exercise. It is difficult both to schedule and to finance such a meeting, even under the best of circumstances. To implement an ISM as a workshop exercise, two innovations were introduced. The elements were identified via a modified Delphi survey, and the structuring exercise was jointly conducted by a nominal group of discussants and a voting audience of workshop participants.

The concept of structural modeling and the issue to be addressed was communicated by mail to each of the workshop participants. The participants were asked to submit an element list of problems which would arise with the emergence of substitutes for food products of animal origin. The original submitted list, which constituted 120 problem elements, was aggregated to 26 elements. These elements were grouped into four categories of principally impacted communities (that is, stakeholders). On the opening day of the workshop, each participant was presented with four pages, each of which contained an untitled list of elements associated exclusively with individual categories of the impacted communities below:

Agricultural inputs industries (5 elements)
Farm production enterprises (6 elements)
Food processing and distribution enterprises (7 elements)
Consumers and the general public (8 elements)

The participants were requested to select the eight elements they considered most important in the context of the issue, but to select at least one element from each page, 8/

The 10 most frequently cited elements which formed the basis for the structuring exercise were 9/:

1. Structural unemployment in the food and fiber sector,
2. Increased concentration and market power in the food industry,
3. Reduced consumption of nutritionally valuable trace elements in animal products, 10/
4. Waste disposal and pollution problems in vegetable and other plant protein processing plants,
5. Greater consumer confusion regarding what is embodied in food products, 11/
6. Inadequate food product additives research programs,
7. Loss of capital investment by livestock producers (including poultry),
8. Increased consumption of potentially health endangering chemical food additives,
9. Obsolescence of agricultural livestock research programs and institutions,
10. Increased unemployment compensation and welfare payments.

The Structuring Exercise

As the exercise was initiated, questions were entertained from both the panel and the audience on the meaning of the element statements, on the function of the ISM program, and on the role of an ISM exercise in a TA. As the exercise progressed, participation in the discussion was restricted to the panel with the audience participating only by voting. The exercise was completed in approximately 1 hour and 40 minutes.

The resulting diagraph (figure 1) displays the group consensus on the structure of the problem components of the general issue of substitutes for food products of animal origin. Policies implemented to alleviate the problems in the lower portion of the diagraph would have a favorable influence on all the problem elements, whereas policies implemented on problems in the upper portion could be considered as dealing with the more symptomatic aspects. The hierarchical inference drawn from responses to the relational questions on pairs of elements is that elements 10, 3, and 8 are aggravated by elements 1 and/or 5, which are in turn aggravated by elements 2, 4, 6, 7, and 9. The group of elements in the lower left corner of the diagraph are interactive, and influence both element 1, structural unemployment in the food and fiber system, element 5, consumer confusion on what is embodied in food products.

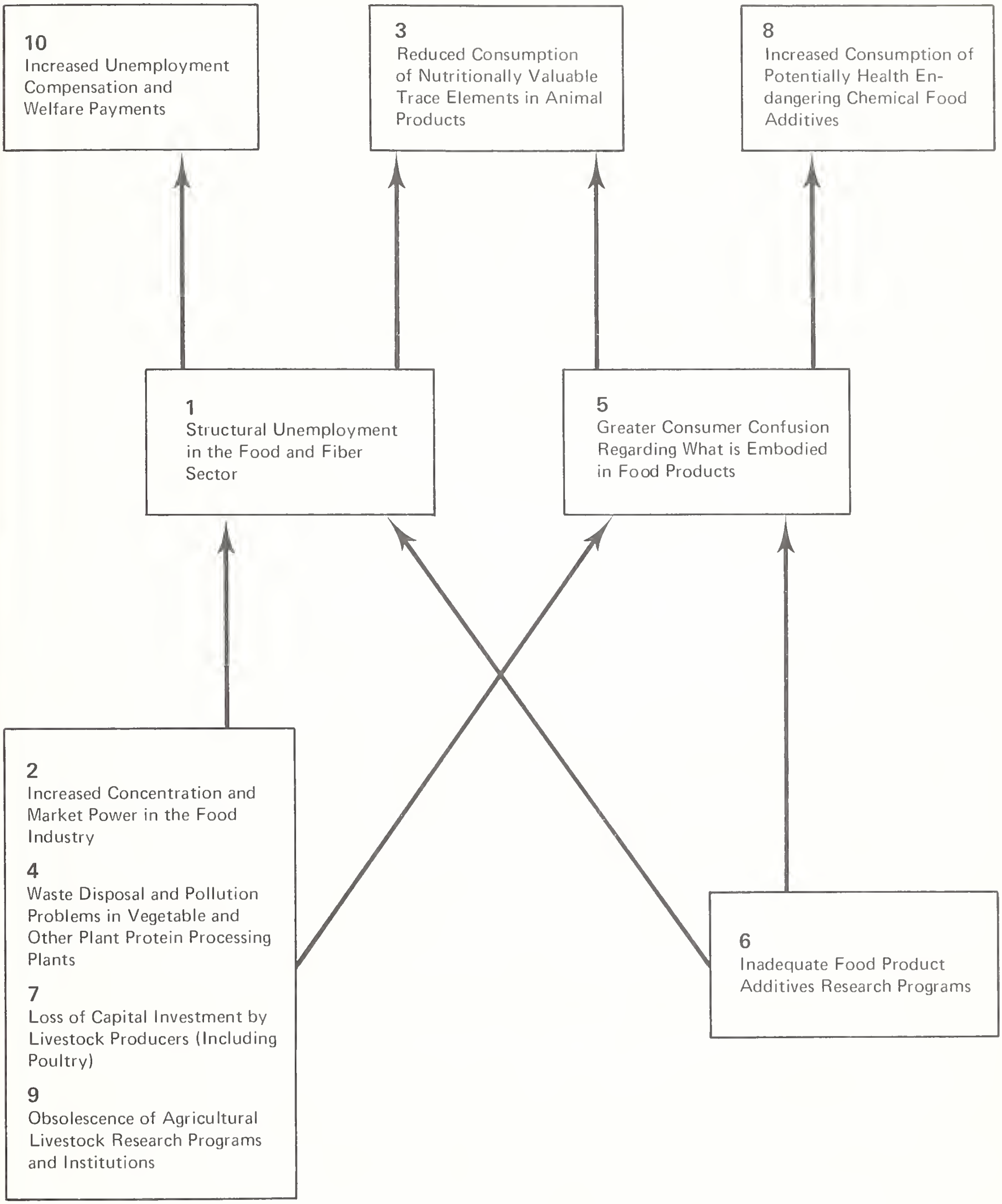
The relationship of the interactive elements (2, 4, 7, and 9) to element 5 may appear weak to some, or even illogical. This may exemplify the danger in reducing the number of elements in the structuring exercise to meet stringent time constraints. The link between the interactive elements and 5 could be the relationship of market concentration and product differentiation and proliferation.

ISM, like Delphi, is a research tool which employs expert opinion. In a nominal group a strong personality may heavily influence the consensus attained. Users of ISM should bear in mind the potential for expert groups as well as individuals to reach illogical conclusions.

Summary and Outlook

The exercise presented here appeared to be well regarded by the workshop participants. The techniques employed in adapting to less than optimal conditions for the exercise may be of general value in increasing the versatility of the method. Ongoing endeavors by developers and practitioners of ISM to improve on the efficiency with which the program can address various relational statements should further increase its potential for technology assessment applications.

Figure 1
Diagraph of ISM Workshop Exercise on the Emergence of Substitutes for Food Products of Animal Origin



FOOTNOTES

1. From Coates, "Technology Assessment at NSF," in Arnstein and Christakis, Perspectives on Technology Assessment. The term "phase" was used to designate the various components of the assessment activity rather than Coates' term "element" so as to avoid confusion with the mathematically based term integral to ISM methodology.
2. See Jean Johnson's paper, "Role of Models in Technology Assessment".
3. A Stanford Research Institute handbook delineates structural models as those that demonstrate the interactions of separate elements of a system or problem, as well as the combined overall effect. See Mitchell, Dodge, Kruzic, Miller, Schwartz and Suta, Handbook of Forecasting Techniques, Center for the Study of Social Policy, Stanford Research Institute, Menlo Park, California, December 1975.
4. An ISTA article by J.C. Duperrin and M. Godet on Conjectural Systems Analysis explores the philosophical basis of structural models and extensions appropriate to technology assessment, Journal of the International Society for Technology Assessment, 1 (4) (1976).
5. In designing and implementing the ISM exercise, the authors benefited from the counsel of David Malone, formerly with the Battelle Memorial Institute and now with the Center for Technology and Administration, the American University.
6. A full discussion of binary matrices in systems modeling may be found in Structuring Complex Systems, John N. Warfield, Battelle Monograph 4, April 1974.
7. This issue was formulated on the basis of suggestions provided by William Gallimore.
8. Forcing the selection of at least some elements reflecting the interests of various communities overcame to some degree the potential for bias reflected by the composition of the workshop group, 38 of whom were ERS economists. The weight of agricultural physical scientists was then additionally enhanced in the selection of the panel of 10 discussants. The three workshop participants who had the highest self-rating on fabricated foods familiarity (from the workshop exercise in selecting candidates for technology assessment) were included, and two additional ERS staff assigned to the regional ARS labs as well as an ARS agricultural physical scientist and a Midwest Research Institute physical scientist. Also on the panel were a Congressional Research Service economist, another ERS economist, and an ERS sociologist.
9. The elements are randomly listed.
10. The panel discussion of nutritionally valuable trace elements actually emphasized the amino acids.
11. The panel took consumer confusion to imply the existence of consumer anxiety.

DETERMINING PRIORITIES OF CANDIDATES FOR TECHNOLOGY ASSESSMENT

by
W. W. Gallimore and W. B. Back
Economic Research Service

Most, if not all, research managers operate with limited resources. As we look ahead to a world more dependent on technology, it is imperative that research and development money be spent wisely. Technology assessments can contribute to this purpose. While no system for determining priorities will ever permit errorless allocation of funds for technology assessment studies, we are nevertheless accountable for just how well we handle the resources assigned to us.

In this paper, a method of allocating priorities to candidates for technology assessment based on responses of participants in this workshop is discussed. The method employed is really an adaptation of two procedures contained in studies financed by the National Science Foundation. 1/ The purpose of the exercise was to give participants in the workshop experience and insight into some proposed methods for sorting out technologies for assessment in the order of their importance and urgency.

Selecting Candidates for Technology Assessments

How can the literally hundreds of possible candidates for technology assessment be put in any order of priority? Regardless of the method of selection, a major input is the judgment of one or a number of individuals on how important a particular candidate technology is likely to be. Because technology may create a complex order of primary and secondary effects, an evaluation of the candidate priorities is preferred from a group with varied expertise. Our panel of experts were the participants in this workshop and as such were probably biased. Twenty-nine of the 37 participants returning ratings were from ERS, thus increasing the possibility of a bias both in the selection and rating of the candidates. The training and experience of a group certainly affects candidate ratings and perhaps the choice of methodology. The criteria for selecting panelists however, will not be covered here except to say that because of the possible immense scope of impacts, the group rating the technologies should cover a broad spectrum of scientific expertise. The problem addressed here is one of exploring methods of bringing together opinions and information from a number of informed people to arrive at a listing of candidates for technology assessment.

One method of selecting candidates for technology assessment is to have each member of a panel rank a number of technologies, add the scores from all panel members for each technology candidate, and then rank the candidates according to these total scores. Another method is to have panel members select for assessment a small number of technology candidates they consider to have the highest priority out of a larger listing. The frequency of selection for each candidate can be summed and the candidates ranked for technology assessment. We did rank our candidates according to frequency of nomination just for the sake of comparison with our other method.

1/ Candidates and Priorities for Technology Assessment, Parts IV and V, Hearings before the Technology Assessment Board of the Office of Technology Assessment Congress of the United States, Ninety-third Congress, second session, June 1974.

For our exercise, a list of 10 technology candidates along with accompanying instructions for rating them was sent to each participant (see exhibit A). Each participant was asked to select 5 of the 10 candidates and then to rate the 5 selected. Thirty-seven participants returned their ratings in time to be included in the ranking process. Our list of technology candidates was kept to a minimum and our rating sheets abbreviated because this was primarily an exercise. However, we believe the resultant rankings have some utility.

The basic premise of this method is that in order to evaluate technology candidates as choices for assessment, it is necessary to ask many of the same kinds of questions that would be asked in an actual technology assessment. Selection of candidates for technology assessment is not in itself a technology assessment. The procedure rests on the assumption that completed assessment of the 10 candidate technologies would have contained sufficient information for ranking them in order of national significance.

For our ranking we calculated an urgency of assessment (UA) score consisting of support scores and a composite impact score. This is represented by the following equation:

$$UA = W_1 \sum_{i=1}^{n} S_1 + W_2 \sum_{i=1}^{n} S_2 + W_3 \sum_{i=1}^{n} S_3 + W_4 \sum_{i-1}^{n} CIS$$

where

S_1 = importance to national priorities and needs

S_2 = strength of institutional support

S_3 = the cost of development and implementation

with S_1, S_2, and S_3 each given a rating of 1 to 5 by each workshop participant.

CIS = composite impact score

$W_1 = .34$, $W_2 = .14$, $W_3 = .19$ and $W_4 = .33$ are the weights given to the components of the UA score. These are averages of weights assigned to these components by eight members of the Technology and Innovation Program Area, NEAD.

n = number of participants' ratings for a given candidate

The reasons for including these components in the UA score and the method of calculating the scores will be briefly covered.

First, it should be stated that each participants' score was adjusted by their familiarity with the selected technology and their estimate of the probability of widespread use by 1986.

Numbers were assigned for familiarity as follows:

Familiar with field	=	.95
Familiar with related field	=	.75
Familiar in some respects with field	=	.50
Casually acquainted	=	.25
Unfamiliar	=	.05

The score or rating of each participant was multiplied by the fraction corresponding to the phrase they checked, thus weighting their answer according to their familiarity with the subject.

Likewise, the scores or ratings were multiplied by the following probabilities assigned for widespread use:

Virtually certain	=	.95
Very likely	=	.75
As likely as not	=	.50
Not very likely	=	.25
Virtually impossible	=	.05

This is one method of letting the expected rate of adoption of the technology affect priorities.

Support scores - After adjusting each participants' score by the above procedure the support scores were summed using the expressions, $W_1 \sum_{i=1}^{n} S_1$, $W_2 \sum_{i=1}^{n} S_2$ and $W_3 \sum_{i=1}^{i} S_3$. The support scores contribute the "political" importance of technology candidates under consideration to the UA score.

Composite impact scores - The composite impact score (CIS) used to represent societal impacts was calculated from the impact effect scores (score sheet number 2) and carries a weight of 33 percent of the UA score. The CIS was calculated by the following equation:

$$CIS = w_1 \sum_{i=1}^{n} e_1^2 + w_2 \sum_{i=1}^{n} e_2^2 + w_3 \sum_{i=1}^{n} e_3^2 + w_4 \sum_{i=1}^{n} e_4^2$$

where

e_1 = long-term economic effects
e_2 = short-term economic effects
e_3 = effect on quality of social life
e_4 = effect on quality of environment
with e_1, e_2, e_3, and e_4 each given a rating of -3 to +3 by each workshop participant.
w_1 = .38, w_2 = .15, w_3 = .22, and w_4 = .25 are the average weights given to these effects by workshop participants.
n = the number of participants' ratings for a given candidate

The score for each effect was squared and the positive and negative effects added to get a total impact measure. The positive and negative effects could have been considered separately in alternative analyses.

Ranking of the 10 Technology Candidates

Ranking by frequency - Workshop participants selected the 5 candidates they wished to score from the list of 10 candidates provided. Participants may have selected candidates for scoring that were the most familiar, applied some of the questions to be later used in rating to choose their own preliminary sorts, or there could have been other reasons for their selections. A sum of the frequency of selection of each candidate is shown in table 1. Development of new pesticides and fabricated foods were selected 28 times and both ranked number one. There could have been a bias toward selecting fabricated foods since it was the example sent to the participants prior to the workshop for the Interpretive Structural Modeling exercise as reported in the paper by Nightingale, et al. Use of solar energy in agriculture and large scale desalinization plants both ranked number 2, each being selected 26 times.

Ranking by UA Scores - Following the outlined procedures, UA scores were calculated for the 10 candidates. The total score reflects, as it should, the frequency of selection as well as the values given for the support scores and the impact effects (table 1). Solar energy ranked first with fabricated foods and new pesticides following closely together in second and third place. There was a very decided gap between the scores for the third-ranked new pesticides and the fourth-ranked automated checkout systems for grocery stores. Also, crop yields-photosynthesis, which ranked third according to frequency of selection, dropped to ninth on the basis of the UA score.

A look at the average scores (total score divided by the number of participants selecting the technology) gives a clue as to why their ordering differs from the one based on frequency of selection. Crop yields-photosynthesis had the lowest average score of the 10 candidates. A check of the work sheets showed the average support score was a high 3.7, but the average for the weight indicating familiarity with the subject was a low .31 and the average probability for widespread use was .33. In comparison, the solar energy technology had a support score average of 3.9, but familiarity with the

subject was .59 and the probability of widespread use was .60. Familiarity with the subject and the probability of widespread use had a major role in our method of calculating the UA scores and in determining the standings of the candidates.

Table 1.--Ranking of candidates for technology assessment by workshop participants

Technology	Frequency		Urgency of ssessment		
	Rank	Times listed	Rank	Total score	Average score
Solar energy in agriculture	2	26	1	38.29	1.63
Fabricated foods	1	28	2	32.94	1.17
New pesticides	1	28	3	31.51	1.12
Automated checkout	6	12	4	17.25	1.43
Large scale desalinization plants	2	26	5	12.52	.49
Protein from microorganisms	4	18	6	11.65	.64
Hybrid wheat replacing other varieties	7	7	7	9.73	1.38
Twinning in beef cattle	5	15	8	8.40	.62
Crop yields-photosynthesis	3	21	9	7.87	.37
Sex control of farm animals	8	4	10	2.04	.50

It seems logical to have adjusted the scoring by some probability reflecting expectations about widespread use. Why spend resources assessing a technology that most everyone agrees has a small chance of adoption? In our exercise, the reductions resulting from lack of familiarity with the subject may be biased because our panel consisted mostly of economists whose expertise is not primarily attuned to technology.

Clearly the UA scores did differentiate among the candidates for technology assessment and in some instances the ranking differed from the one established by simply counting the frequencies of selection. One of the major advantages of a procedure involving rating of support scores and impacts is that it requires disciplined thinking. For those needing to assign priorities on candidates for technology assessment, the procedure illustrated in this expercise provides a means for possibly changing priorities as conditions change. For example, a significant change in institutional support could be incorporated in the system without having to rate a candidate again for all other criteria.

Concluding Remarks

This exercise was intended primarily as a teaching tool and in its application, as such, appeared to be useful for determining the priorities of candidates for technology assessment. However, the individual score sheets suggested that some of the participants may not have been entirely consistent in their responses. For example, some participants indicated they were not familiar with a candidate but put a high probability on widespread use by 1986. However, part of this seeming inconsistency may have resulted from impreciseness of the definitions and instructions furnished the participants.

There was some confusion about the use of score sheet number 1. This should not have biased the overall scores significantly, however, since only a small number of errors were made.

The omission of a definition for "familiarity with a technology" probably created a more serious problem. Then too, the use of more than 10 candidates for technology assessment perhaps would have allowed a better feel for the procedure and resulted in a more realistic test. Nevertheless, the exercise accomplished its purpose.

Exhibit A

Candidates for Technology Assessment 1/

1. New pesticides based on sex attractants and/or bacterial or viral substitutes for chemicals

2. Twinning in beef cattle

3. Use of solar energy for heating, curing, and drying in agricultural production

4. Production of protein by micro-organisms acting on waste materials or petroleum products

5. Fabricated foods using soy and other proteins--properly textured and flavored

6. Hybrid wheat replacing all current wheat varieties

7. Improvement of crop yield and quality through altering the process of photosynthesis

8. Sex control of poultry and farm animals

9. Fully automated "checkout" at supermarkets

10. Large scale desalinization plants economically producing water for irrigation

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1/ The number by each candidate is for identification on the score sheet of the five selected and does not have any other significance.

SCORE SHEET NO. 1

Scoring of Candidates

	Candidate Number				
	Rating of Candidate				
1. Importance to national priorities and needs					
2. Strength of institutional support					
3. Cost of development and implementation					
4. Familiarity with the technology or most relevant science					
Familiar in field					
Familiar in related field					
Familiar with some aspects					
Casually acquainted					
Unfamiliar					
5. Estimated probability of widespread use by 1986					
Virtually certain					
Very likely					
As likely as not					
Not very likely					
Virtually impossible					

INSTRUCTIONS: Place the number corresponding to each of the five candidates you selected to rate in one of the boxes heading the columns. Rate each candidate with a 1, 2, 3, 4 or 5 for the first three criteria. Refer to the attached sheet for a brief explanation of the criteria. For criteria 4 and 5, make one check for each candidate by the phrase you select.

Name of individual completing score sheet ______________________________.

Explanation of Scoring Criteria for Ranking
Candidates for Technology Assessment

1. Importance to National Priorities and Needs

This calls for a judgment as to the National (as opposed to State or local) importance and urgency of the problem area to which the technology relates as well as the contribution the particular technology can be expected to make. National priorities or needs could relate to national objectives such as conservation of energy, reduction of inflation, production for exports, etc. A score of one indicates a low priority, a score of five would be the highest national priority.

2. Strength of Institutional Support

This is a net measure of the strength of the groups or interests supporting the innovation, including industry, citizens groups, professional groups, government agencies, congressional supporters, etc. If opposing groups about balanced supporting groups, a low score should be given. Consider only existing, not potential, support or opposition.

3. Cost of Development and Implementation

This is a measure of the total expenditure, either public or private, required to complete development and implementation of the innovation. The premise of this question is that it is more important to assess a program that is going to cost one billion dollars than one that is going to cost one million dollars. If startup costs are minimal but operating costs are expected to be large, then consider annual costs for ranking. A score of one would indicate an estimated relatively low expenditure.

4. Familiarity With the Technology or Most Relevant Science

This is your assessment of your knowledge of the candidate. Check the phrase that best describes your knowledge of the technology or a field of science related to the technology.

5. Estimated Probability of Widespread Use by 1986

Widespread is defined as being out of the laboratory and employed in 25 percent of its potential applications <u>or</u> out of the formulation stage and placed in practice if it is a technology that can be placed in use by an individual.

SCORE SHEET NO. 2

Determining the Impact Scores for the Five
Selected Candidate Technologies

	Candidate Number				
	Rating of Candidates				
A. Long-term economic effects					
B. Short-term economic effects					
C. Effect on quality of social life					
D. Effect on quality of environment					

Provide your estimate of the weight that should be given to the four criteria by distributing 100 points among them.

	Points
A. Long-term economic effects	______
B. Short-term economic effects	______
C. Effect on quality of social life	______
D. Effect on quality of environment	______
Total	100

INSTRUCTIONS: Refer to the attached sheet describing the four impact criteria and then rate each of the five selected candidates for each effect. The scores range from a -3 (most negative impact) to a +3 (most positive impact). A score of 0 indicates the positive and negative effects are considered about equal.

Name of individual completing score sheet ____.

Explanation of Criteria for Determining Impact Scores

Long-term economic effects - The extent to which the technology will result in a net increase or decrease in the total quantity of economic goods and services produced in the long term relative to a baseline. Also consider the net effect on the supply of resources in critical supply, such as energy. A favorable impact would generally reflect a more efficient utilization of natural resources, increased productivity of labor, or increased productivity of capital. An unfavorable economic impact would mean the contrary. Also included are improvements or declines in aspects of the standard of living such as convenience, variety, quality, etc.

Short-term economic effects - Refers to the net effect of short-term or localized unemployment or increased employment or other effects of a transient nature. If both beneficial and harmful effects are occuring equally at the same time, they should balance out. However, the negative impact may receive the greater weight since for example the simple balancing of jobs lost and gained ignores the problems of dislocation.

Effect on quality of social life - Includes a variety of aspects, including the equity of income distribution; social mobility; diversity of opportunity and freedom of choice; the presence or absence of racial or other kinds of discrimination; the propensity of various groups to be cooperative or disruptive; and the general morale of society as a whole. These are related to income and employment but are considered separately for assessment. These and other social aspects could be scored positively or negatively.

Effect on quality of the environment - Refers to externalities, or public and private disservices resulting from economic activities in a nonmarket realm. Pollution, congestion, and accidents are the major categories. For example, if the technology increases the amount of pollution or congestion generated by production and/or consumption of the goods or services, it gets a negative score or conversely a positive score if the opposite is true.

REPORT OF RAPPORTEUR GROUP I

by
Robert V. Enochian (Chairman of Group), Donald D. Durost,
Clarence A. Moore, and Clarence D. Rogers
Economic Research Service

The purpose of any workshop is for a group with a common interest to address an issue or issues with which it has a concern.

Answers to certain questions are basic to an understanding of the role of technology assessment in social decisionmaking and how ERS can best participate in technology assessments. These questions can be paraphased as follows:

1. What is technology?
2. What is technology assessment (TA)?
3. What are the forces causing the apparent growing interest in TA?
4. Is ERS now doing TA? Can it be improved?
5. What is the methodology for doing a TA?
6. How does one select a candidate for TA?
7. When does one do a TA?
8. What should be included in a TA?
9. How do we know TA will give us the "right" answers?
10. How does one put bounds on a TA?
11. How does one evaluate the tradeoffs between the beneficial and adverse impacts of technology?
12. Who assesses the assessors?
13. Who uses the results of a TA?
14. Where and how does ERS go from here?

Although these questions are rather simple and straightforward, their answers are not. We believe the following would be an encompassing definition of technology assessment:

> Technology assessment is the formal, systematic, interdisciplinary examination of an existing, newly emerging, or prospective technology with the objective of identifying and estimating first and second order costs and consequences, over time, in terms of the economic, social, demographic, environmental, legal, political, institutional, and other possible impacts of the technology, including those consequences which may not have been anticipated, intended, or desired by the inventors, and of specifying the full range of alternative courses of action for managing, modifying, or monitoring the effects of the technology.

Any assessment that does not meet the criteria specified in this definition can only be termed a partial assessment.

Why have we become so interested in technology assessment? The public is becoming more and more concerned with the adverse impacts of technology and through the spokesmen of the ecological-environmental movement is asking for factual information on which better policy decisions regarding technological innovations can be made. ERS can perform its mission better by fuller knowledge of the secondary and tertiary impacts of new technology and, therefore, believes we need to expand our efforts in this area.

ERS is now engaged in a number of partial technology assessments. On the second day of the conference we heard reports from 10 areas of study. Eight of these were being done by ERS, one by the Agricultural Research Service (ARS), and one by a private

research institute. These reports varied from marshland management to farm mechanization to evaluating technology impact statements used in research planning. The tools used for assessing these technologies varied from subjective assessments to sophisticated econometric models. Some of the studies started out at the micro level and then expanded to the macro, while other studies were only at the macro level. Most of the studies went only as far as they had "hard" data on which to base analyses. Thus, most assessments considered only the primary impacts. The studies of tobacco mechanization, irrigation technology, and coal mining being done by ERS are examples of studies that are going beyond the primary impacts to study the effects of technology on the community.

None of the studies could qualify as being "holistic" as defined by Coates or by our definition of TA. The nearest to this was the "Assessment of Integrated Hog Farming" reported by Ivan Smith of the Midwest Research Institute. This study considered the impacts of technological, institutional, political, and social forces, and policy issues and depended heavily on the subjective measurement of the impacts. However, hard data were used where possible, particularly in projecting hog enterprises and farm numbers.

These studies demonstrated that there is no one method or technique for making technology assessments. Studying an adopted technology versus a potential technology requires different tools. One participant recommended that the methodology used for TA should not be institutionalized since it tends to become fixed. The methodology must remain flexible depending upon the problem. Hard data are not available for assessing secondary impacts so subjective methods must be used if we are going to assess these impacts. One person suggested that technology assessment is an "art" rather than a neat step-by-step mathematical procedure.

Technology assessment beyond the primary impacts will get into high risk areas. Some issues that may seem important may turn out to be unimportant after investigation. Thus, time and resources may be wasted, although negative results do add to our knowledge. There are techniques available that may reduce these risks.

The third day of the conference went into some of the methods that can be used for technology assessment and for minimizing the risks of going down blind alleys.

Most of the methods and techniques that were discussed would be appropriate for partial technology assessments. Only one of the nine papers described an holistic approach. This paper, "The Role of Models in Technology Assessment," by J. M. Johnson, set forth three unique roles of models in technology assessment. Topics for four of the methodology papers were scenario writing, simulation, input-output, and linear programming. Scenario writing can be used in structuring research. It can be used to specify the branches on the decision tree, hence directing attention to the various alternatives that are available. Scenarios may be analyzed using simulation, input-output or linear programming analysis. These research tools are useful in making partial assessments during different phases of project development.

These tools provide the decisionmaker with useful information, but they are not without their weaknesses. As always, we must be ready to cope with data problems and model specification problems. We should also remember that even though the use of models has been found to give a much higher probability of success than random thinking, intutition, or dreams, it is not a panacea but merely a tool to increase the efficiency with which the human mind solves problems and rationalizes facts and relationships. This is true for TA as it is in any human endeavor.

Another source of danger in a TA is the possibility of overlooking the potential effects of exogenous variables. If we were to study the whole gamut of historical technological development, we suspect that we would find most of the negative impacts of particular technologies were canceled out by positive impacts from other technologies. If so, what do we do about similar potential exogenous forces when making assessments of new technology? They will be difficult to predict, but they are too important to ignore.

Still another danger might arise through the establishment of cause-effect relationships based on historical data, information, or facts. In this context, a good deal of our formulation of the problem and the hypotheses in TA's will likely be deter-

mined by the relationships we have imbedded in our subconscious minds. The real problem may well be to free our thinking from too much dependence on these historical preconceptions since future developments may not occur in similar fashion or at the same rate as past developments. Nor may they have the same impacts. As an example, it took many years for hybrid corn to be universally adopted, but only a few years for hybrid sorghum.

A major problem in some TA's may be the "cutting off" or bounding of the assessment. This is so because the effects of any major technology can go on and on reverberating throughout the entire fabric of society like the concentric rings from a pebble tossed in a pool of water. In some cases, resource limitations will dictate bounds; in others, demands by potential client groups for timely answers may restrict what can be done in a given time. Where time and resources are limited, those areas of expected minimum impact should be avoided. Low priority should be placed on factors that the market itself will "assess," provided no major safety or social aspects are anticipated - for example, acceptance of a new product where the user has a choice. Where no choice exists, such as the use of a preservative or additive to the food supply, the impacts should be assessed.

In cases where possibly important factors cannot be assessed because of time and resource constraints, the TA should provide suggested means of monitoring potential impacts as the technology is used and specifying alternative courses of action depending upon the outcome of the results of monitoring.

Technological change in inevitable. As Florman puts it, "The power to invent, build, etc., is the essence of humanity. . . .men are driven to technological creativity because of instincts hardly less basic than hunger and sex." 1/ The question mankind faces is whether technological means will outpace the maturity of human judgment to control it for mankind's optimum welfare. If it was ever true, we can no longer hold on to the notion that "an individual who intends only his own gain is led by an invisible hand to promote the public welfare." With any new development, there is always a welfare redistribution. The questions for the policymaker are: What are the tradeoffs? Who bears the costs and who receives the benefits?

The ultimate objective of TA is to provide policy guidance. This does not assume that the effects of technology can be reduced to a set of equations that balance the good impacts against the bad and thereby simplify policy decisions on new technology. Such an assumption would neglect the fact that we will never be able to identify, let alone quantify, the many side effects of new technology. Furthermore, no human mind can comprehend the complex tradeoffs between man's inventions and their social and environmental impacts. Every endeavor of man is and always will be "human." That is to say, "There is no logic and epistemology independent of psychology." 2/ So, who assesses the assessors and the policymakers? They, too, are human. As Georgescu-Roegen so logically reminds us, "Every individual knows his own means and ends, no one knows the means and ends of others." 3/

Where does this leave the policymaker? Even if we accept Coates' admonition that what needs to be done is to specify the full range of alternatives with their probabilities, how do we balance the "good" against the "bad" impacts? If it is to be an elitist decision, there is still human judgment involved. If it is by majority rule, choices will be made with much less knowledge. According to Susskind, " . . . the greatest problem is that no real basis exists on which anyone could compute what constitutes the public interest." 4/ Susskind goes on to say that " . . . what is most urgently needed is . . . some hard work to arrive at nationally and internationally acceptable criteria against which the 'goods' and the 'bads' of technological developments can be measured."

1/ Samuel C. Florman, Existential Pleasures of Engineering. St. Martins Press.
2/ H. Poincare, "Mathematics and Science: Last Essays." New York, 1963, p. 64.
3/ Nicholas, Georgescu-Roegen, "The Entropy Law and the Economic Process." Harvard University Press.
4/ Charles Susskind, "Understanding Technology." The John Hopkins Press, Baltimore and London.

Does this mean that TA has no particular value and that ERS has no role in TA? Quite the contrary. It merely recognizes that the ultimate clientele for TA in a democratic society is the voting public.

We suggest that ERS begin increasing its involvement in TA by funding a meeting which brings together in a "think tank" atmosphere a select group of about 7 to 10 persons for at least a week - longer if necessary - with the following assignment: 1) To identify for a TA, an emerging technological development in agriculture which can be expected to have adverse, as well as beneficial, social, and/or environmental impacts; 2) to outline all of the probable impacts the new technology can be expected to have; 3) to identify those impacts that should be assessed with suggested methodologies; 4) to specify the disciplines of the team members that should address the problem; 5) to develop a workplan for engaging the problem including the identification of the agencies that team members come from, how they should be compensated, where they should be located, who the leader should be, a probable budget, and so forth; and 6) finally, to specify when, how, and who should monitor the project as it proceeds and the criteria for evaluating each stage of progress.

Representatives in this "project identification" meeting should be from at least the following agencies: ERS, ARS, the Office of Management and Budget, the Congressional Office of Technology Assessment, the National Association of State Universities and Land Grant Colleges, and Ralph Nader's group or the Agribusiness Accountability Project. They should be appraised well in advance of the meeting what its purpose is so that they can begin getting inputs from colleagues and start the thinking phase.

We would like to close our discussion with a caveat to researchers. Technology assessment seems to be rapidly becoming a popular catch phrase to justify research similar to the way the phrase "agriculture adjustment" was used to few years ago. A danger exists in overpromoting TA as having answers to all of the social and economic problems in agriculture. This "band-wagon" effect could eventually result in discrediting TA even for problems in which it has an appropriate role.

REPORT OF RAPPORTEUR GROUP II

by
L. D. Schnake (Chairman of Group),
Ray Corkern, Gary Frank,
Robert McElroy, and Warren Trotter
Economic Research Service

This report results from independent, individual assessments of the entire workshop by the authors, and from consultation with workshop participants.

This assessment of the workshop follows the guidelines listed below:

A. Did the given paper or exercise satisfy the stated purposes of this workshop, namely,
   1. To facilitate improved communications among those within ERS engaged in technology assessment and
   2. To contribute to improved selection, planning coordination, and conduct of technology assessment components of our research?

B. What were the significant contributions of the open discussion?

This report addresses five major headings that were used by the authors to evaluate the workshop: (1) Structure of the 1976 Workshop; (2) Structure of a future group meeting; (3) Management Considerations; (4) Recommendations and additional comments; and (5) Conclusion.

Attendance. The workshop assembled a group of people highly qualified in their own right. Improved communication among those present from ERS was facilitated and everyone was allowed to express themselves fully. However, the size of the group may have been a little too large.

Presentations. The papers presented could be classed into 5 categories:

(1) integration of TA process into current ERS;
(2) philosophical, theoretical view of TA process;
(3) partial technology assessments;
(4) examples of technology assessments; and
(5) tools to be used in technology assessments.

The ordering of presentations could have been improved for this meeting. For example, the Smith, Johnson, and Carr papers included elsewhere in these proceedings should have followed the Coates presentation. This rapporteur group felt some of the papers presented were not appropriate for this workshop on TA. However, one or two would have been appropriate as a learning device as to what TA is not. For example, some speakers used actual application of techniques in their presentations, but the emphasis was on the subject of the particular study rather than on how to use the technique. Still others discussed the application of a technique, but the emphasis was on the theoretical development of the methodology and the audience never saw how to do it.

The ISM experiment was obviously conducted under adverse conditions, which is no fault of those who conducted the experiment, and it was stated that the witnessed conduct of the exercise was not normal operating procedure. Future exercises of this type deserve more time. Perhaps more initial explanation or distribution of the results from the mail-in activity would be appropriate and an outsider should critique the exercise to point out such things as biases which occur from a group such as ours.

It is felt that future meetings should be structured as follows:

(1) Establish a central theme applicable to the technology assessment process. Perhaps a mini-TA would be an appropriate theme for a future session with the

phase of the process as presented by one paper carried out by mail or phone prior to arrival at the meeting.

(2) The printed program should be delineated or structured to reflect a continuity, and if papers are presented, they should be in the hands of the rapporteurs at least 1 week prior to the session.

(3) There should be no nighttime exercises for a large group. Perhaps nighttime exercises are feasible for a small group to prepare a report for a larger group, but that should be gauged according to the daytime load.

(4) All participants should be housed together to facilitate better interpersonal contact.

(5) Chairpersons selected for future sessions should have no personal involvement in the production of the papers presented.

(6) Rapporteurs should be allocated time for developing responses--they were not this time.

(7) A smaller, selected group to include more people outside traditional channels would moderate the research community's bias present at the current workshop.

(8) The Administrator's Office of ERS should be represented at all sessions of a future workshop.

The ERS-ARS position must be explored with regard to initiation and management of technology assessment input and consequent output (that is, publication of results).

We acknowledge projects which can be classified as partial TA's, but in the future improved coordination between research areas must exist for successful TA research efforts. A successful team has members who: have "thick skins"; ask "dirty questions"; communicate freely; are self starters; are flexible; can accept much criticism; and are good "weeders". There must be an understanding of the TA process and all its associated managerial ramifications from top management down to the researcher level, which does not now exist.

Finally, there must be quality control credibility. The mechanism to assure this must be one which is public. We must be prepared to deal with the negatives. This procedure must be made clear and agreed upon before the TA begins.

Increased efforts should be made by ERS to communicate with other Government agencies, State and local governments, universities, and the populace in general to facilitate expanded generation and analyses of policy options in ERS research.

A paper on the ERS-ARS cooperative work providing historical perspective would have been quite appropriate at the subject workshop.

The workshop accomplished more to improve communications among those within ERS engaged in technology assessment, {objective (1)} than to contribute to improved selection, planning, coordination, and conduct of the technology assessment components of our research {objective (2)}.

There are segments of society that feel USDA has traditionally not done a good job of communicating what it has done for society. Perhaps technology assessment will be a vehicle which will lead to a better view of the role of USDA and agriculture's contribution to this society.

Technology assessment is not a panacea for man's problems. Man has been longing to know the future since time immemorial. Everyone seems to think they would like to have a crystal ball in which their future is revealed when they take a peek. It seems perhaps that TA might serve like spectacles, that is, not correct the imperfection of the eye, but allow the individual better vision as he looks into the crystal ball.

The Administrator gives high priority to TA work and this panel strongly concurs.

APPENDIX

** AN ASSESSMENT OF MINIMUM TILLAGE

by
W. B. Back
Economic Research Service

During 1972-75, the Office of Planning and Evaluation, a staff group within the Office of the Secretary of Agriculture, conducted an assessment of new crop production techniques to reduce tillage to the minimum consistent with local soil, climate, and economic conditions. This assessment was intended to be illustrative of the kind of studies needed to provide USDA program and policy officials with more timely and complete information on the primary, secondary, and tertiary impacts of new agricultural technology. The expected result was a study that would start an appropriate assessment of minimum tillage, and that would stimulate professional interest in continuing and completing it. Instead, the results have been widely publicized and distributed, mainly within the agricultural establishment, as if they were authentic research findings.1/ This summary originally was prepared for the special issue of the "Journal of the International Society for Technology Assessment." It is reprinted here in order to increase its availability to professional workers in agriculture.

Background and State of the Technologies

Minimum tillage is a concept rather than a specific technology or package of technologies applicable at all times to all situations. Almost any trashy fallow or stubble-mulching practice was considered minimum tillage in the Great Plains in 1940. In 1976, this has to be carried out under specifications tailored to climate and soil conditions, and combined with minimal plowing and other soil manipulation, to qualify as minimum tillage. In the Midwest, and much of the East, minimum tillage first was associated with elimination of cultivations or soil manipulations following plowing and planting; now it includes no plowing or other preplanting operations for many soil situations. Research, development, and education have resulted in a continous reduction in tillage. Recent research and development has stressed "no-till"--the direct planting of a crop without plowing or seedbed preparation in a sod or the residue of a preceding crop, and the subsequent absence of any cultivation, together with complete reliance upon chemicals for weed, insect, and disease control. The ultimate minimum tillage is "no-till." Such an extreme may never be technically or economically feasible for a large portion of the cultivated areas in the United States.

The use of 2, 4-D weed killer following World War II and the subsequent technological developments in the composition and application of herbicides made practical the substitution of chemicals for tillage operations. Chemical control of diseases and insects is required if tillage reductions are to be continued.

According to 1974 estimates by the Soil Conservation Service (SCS), about 10 percent of the cropped acreage in the continental United States was minimum tilled. Separate surveys carried out by the editorial staff of "No-Till Farmer" magazine indicated that about 20 percent of the total minimum tilled acreage in 1974 was "no-till." Minimum tillage, including "no-till," seemed to be spreading rapidly. About a 10 fold increase in crop acreage minimum tilled occurred during 1963-1974.

Methods 2/

The Office of Planning and Evaluation was not staffed by experts in the sciences contributing to the technologies involved in minimum tillage (soil science, agronomy, plant genetics, chemistry, engineering, and so forth). Thus, finding and implementing workable procedures for getting the needed technical inputs into the process were key elements in the overall procedure. It was necessary to acquire this expertise at nominal or no cost to the office.

The first draft of the report was prepared from available literature. It included the minimum and "no-till" acreage estimates by SCS and "No-Till Farmer." Projections of adoption through the year 2000 were made, based upon the acreage estimates of 1963-1974, an assumed logistic function, assumed maximum attainable adoption of 100 percent for minimum till and 80 percent for "no-till," and other assumptions relating to technological advance, crop production, prices, farm policy, and foreign trade. 3/ The first draft report, including "rationalizations" of impacts, was completed in April 1974. A meeting with representatives of the research, education, and other USDA agencies with direct interest or responsibility in the subject then was called. Their cooperation was solicited in a procedure essentially amounting to obtaining reviews, comments, suggestions, and assistance from those individuals within the agencies, the land-grant universities, or elsewhere, who had the requisite expertise. A covering memorandum requesting this assistance was attached to the draft report, and a first-stage review and reaction was solicited by the agency representatives from the experts in the Washington metropolitan area. It was felt that the manuscript needed significant improvement prior to distribution to a nationwide audience of experts.

The feedback obtained in this first stage did provide inputs for substantial changes in the manuscript. Another draft, completed in July 1974, was distributed nationwide by the agency representatives for review. Feedback from that review process was used in making another complete revision of the manuscript. It was evident at this stage that the experts disagreed on some very fundamental matters, such as the extent of adverse environmental impact from pesticide usage. The office staff may have chosen to compromise on such questions. That's because the staff did not consider itself qualified to decide what was "right."

A third stage of the process consisted of obtaining final reviews from a small, select group of experts--those who had made the greater contributions in the earlier reviews and who exhibited the most interest in the study. The final report, as published in 1975, contained the final suggestions from members of the select group. 4/

Digest of Results

The principal findings in this assessment of minimum tillage were:

The estimated 33 million acres of minimum tilled land in 1974 were about 10 percent of total crop acreage in the continental United States. In 1964, only about 5 million acres were minimum tilled. The crops with the most minimum tilled acres were also the crops with the greatest potential for expansion in minimum tillage: corn, sorghum, soybeans, and small grains.

More than 80 percent of all crop acreage could be minimum tilled by the year 2000, and nearly half of that could be "no-tilled." 5/

Harvested crop acreage could be increased by 20 million acres by the year 2000 (about a 5-percent increase) because of minimum tillage; about 15 million of these acres would be due to multicropping made possible by minimum tillage, and the other 5 million would be through expansion onto lands unsafe to cultivate without the use of minimum tillage because of erosion.

A 5-percent increase in total farm output by the year 2000 could be obtained through widespread adoption of minimum tillage.

Prospects of significant savings in production costs (especially labor) appeared to be the principal reason for farmer adoption of reduced tillage practices; on a national basis, resource savings to farmers could approach $1.6 billion annually by the year 2000.

Savings in energy costs for operating farm machinery (about $275 million annually) would be approximately offset by increased pesticide costs (about $300 million annually).

The need to comply with water and air pollution standards or regulations could encourage more rapid adoption of minimum tillage.

Soil losses through erosion could be cut by 50 percent by the year 2000. This impact could be the principal public benefit of minimum tillage. 6/

Increased pesticide usage associated with expansion in minimum tillage could increase social concerns about environmental pollution unless future technological developments reduce the potential adverse effects of pesticide use or unless the transfer of chemicals off the farm is reduced through a decrease in soil erosion.

Available information was inadequate for properly assessing all the impacts of minimum tillage.

Implications

The published report on the minimum tillage study stressed the need for additional research relating to the environmental hazards of expanding minimum tillage, and for administrative arrangements for systematically monitoring the adoption of this technology. Needed research encompassed biological substitutes for chemicals, such as insect and disease resistant varieties of plants, as well as development of more effective, but safer, herbicides. The proposed monitoring system was associated with the knowledge and data base needs for periodically updating the assessment of minimum tillage.

An unreported implication was that the primary basis for the substantial Federal investment in conservation for holding soil erosion losses to a socially acceptable minimum could be nearly eliminated by the maximum expansion of minimum tillage. 7/

Footnotes

1. USDA agencies distributed 1,500 copies of the original report. In addition, the U.S. Senate Committee on Agriculture and Forestry published and distributed the report as a Committee Print in 1975 and the Economic Research Service, USDA, published a summary of the report findings as "Farming Minus the Plow," in "The Farm Index," May 1976.

2. This article is an extract or digest of previously published material relating to the minimum tillage study except this section on methods. The previously published materials did not contain a description of the process used in tapping the expertise from the various agricultural sciences involved with minimum tillage technology.

3. Most of the assumptions underlying the projected adoption of minimum tillage were based on either rational and/or empirical support. Nevertheless, there was no intent to forecast a most probable expansion path; rather, the intent was to set an upper limit on rate and extent of adoption, which might be in fact a very improbable pathway for the future.

4. The individuals especially helpful throughout the review and report development process were Harold Owens, Extension Service; Professor G. B. Triplett, Jr., and associates, Ohio Agricultural Research and Development Center; and Dr. J. L. Apple and associates, North Carolina Agricultural Experiment Station.

5. A statement such as this is intended to be an estimated upper limit, not a probable outcome.

6. The conservation aspects of minimum tillage are considered of such significance by many agricultural scientists to warrant labelling the collective practices "conservation tillage" rather than "minimum tillage." Much of the pertinent research and development has been stimulated by scientists' interests in soil conservation. In the original report on the study, it was pointed out that tillage practices geared to the maximum achievement of soil conservation may or may not be the minimum in soil manipulation technically and economically feasible to farmers. Thus the term, "minimum" rather than "conservation" tillage was adopted for the report.

7. Federal activities potentially redundant following widespread adoption of minimum tillage would be much of the technical assistance program of the Soil Conservation Service, and related educational work of the Federal and State extension services. Leaders in these activities are among the current activists in promoting minimum tillage.

ABOUT THE AUTHORS
(listed alphabetically)

W.B. Back is project leader, assessment of technology in the food and fiber system, National Economic Analysis Division, ERS, Washington, D.C.

Lloyd D. Bender is leader of the economic development component of an Environmental Protection Agency-funded coal impact study, Economic Development Division, ERS, Bozeman, Montana.

Barry A. Carr is a staff specialist in agricultural policy, Congressional Research Service, Library of Congress.

Lon Cesal is leader, industrial location program area, Economic Development Division, ERS, Washington, D.C.

Joseph F. Coates is Assistant to the Director, Office of Technology Assessment, U.S. Congress.

Jeff V. Conopask is a regional economist researching energy resource development within the Economic Development Division, ERS, Washington, D.C.

Ray S. Corkern is research advisor and liaison economist, National Economic Analysis Division, ERS, Southern Regional Research Center, New Orleans, Louisiana.

Velmar W. Davis is Deputy Director (environmental economic studies), Natural Resource Economics Division, ERS, Washington, D.C.

Donald D. Durost is project leader, inputs productivity and technology, National Economic Analysis Division, ERS, Washington, D.C.

Robert V. Enochian is research advisor and liaison economist, National Economic Analysis Division, ERS, Western Research Center, Albany, Calfornia.

Howard M. Gadberry is member of professional staff, Midwest Research Institute, Kansas City, Missouri.

William W. Gallimore is project leader, substitutes and synthetics, food and fiber sector, National Economic Analysis Division, ERS, Washington, D.C.

Frank Gary is agricultural economist researching dairy production economics, Commodity Economics Division, ERS, Washington, D.C.

Virden L. Harrison is agricultural economist researching meat animal production, Commodity Economics Division, ERS, Clay Center, Nebraska.

Jean M. Johnson is a program manager, Research Applied to National Needs, National Science Foundation.

James E. Kirkley is agricultural economist participating in development of farm input index series, National Economic Analysis Division, ERS, Washington, D.C.

Yao-chi Lu is project leader, productivity and technological change in U.S. agriculture, National Economic Analysis Division, ERS, Washington, D.C.

James D. Maloney is member of professional staff, Midwest Research Institute, Kansas City, Missouri.

Robert G. McElroy is agricultural economist researching new technology in southern agriculture, National Economic Analysis Division, ERS, Richard B. Russell Research Center, Athens, Georgia.

Douglas McNiel is agricultural economist researching impacts of new technology in meat packing, National Economic Analysis Division, ERS, Washington, D.C.

Dwight L. Miller is Assistant Director, Northern Regional Research Center, Agricultural Research Service, Peoria, Illinois.

Marshall E. Miller is program area leader, Technology and Innovation in the Food and Fiber Sector, National Economic Analysis Division, ERS, Washington, D.C.

Clarence A. Moore is research and advisory economist, National Economic Analysis Division, ERS, Northern Regional Research Center, Peoria, Illinois.

Ray W. Nightingale is agricultural economist researching U.S. agricultural export expansion and automation in food retailing, National Economic Analysis Division, ERS, Wahsington, D.C.

Thomas A. Niles is economist researching interindustry transactions of the farm sector, National Economic Analysis Division, ERS, Washington, D.C.

Frank H. Osterhoudt is agricultural economist, Foreign Agricultural Service, LACIE project, Washington, D.C.

Wayne D. Rasmussen is program area leader, Agricultural History, National Economic Analysis Division, ERS, Washington, D.C.

Gordon E. Rodewald, Jr., is agricultural economist researching impacts of new tractor power technology, National Economic Analysis Division, ERS, Pullman, Washington.

Clarence D. Rogers is operations research analyst researching economics of marketing cotton textile products, Commodity Economics Division, ERS, Clemson, South Carolina.

Gerald E. Schluter is agricultural economist analyzing linkages between agriculture and the rest of the economy, National Economic Analysis Division, ERS, Washington, D.C.

L.D. Schnake is agricultural economist researching production, processing and marketing grain, Commodity Economics Division, ERS, Manhattan, Kansas.

Owen K. Shugars is project leader, tobacco, Commodity Economics Division, ERS, Washington, D.C.

Ivan C. Smith is senior advisor, agriculture/environment, Midwest Research Institute, Kansas City, Missouri.

Richard G. Stuby is rural sociologist researching social indicators and levels of development in nonmetro counties, Economic Development Division, Washington, D.C.

Harold H. Taylor is research advisory and liaison economist, National Economic Analysis Division, ERS, Eastern Regional Research Center, Wyndmoor, Pennsylvania.

Howard R. Thomas is project leader, Snake River type IV study, National Resource Economics Division, ERS, Corvallis, Oregon.

Theodore Thornton is agricultural economist researching new technology in tractor power and technology in bioconversion of farm residues into energy, National Economic Analysis Division, ERS, Washington, D.C.

Larry Traub is agricultural economist researching market impacts of new or modified technologies in food forms, National Economic Analysis Division, ERS, Washington, D.C.

Warren K. Trotter is research advisory and liaison economist, National Economic Analysis Division, ERS, Richard B. Russell Research Center, Athens, Georgia.

Glen E. Vanden Berg is Associate Deputy Administrator, Northeast Region, Agricultural Research Service, Beltsville, Maryland.

Quentin West is Administrator, Economic Research Service, and United States Department of Agriculture liaison with the Office of Technology Assessment, Washington, D.C.

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